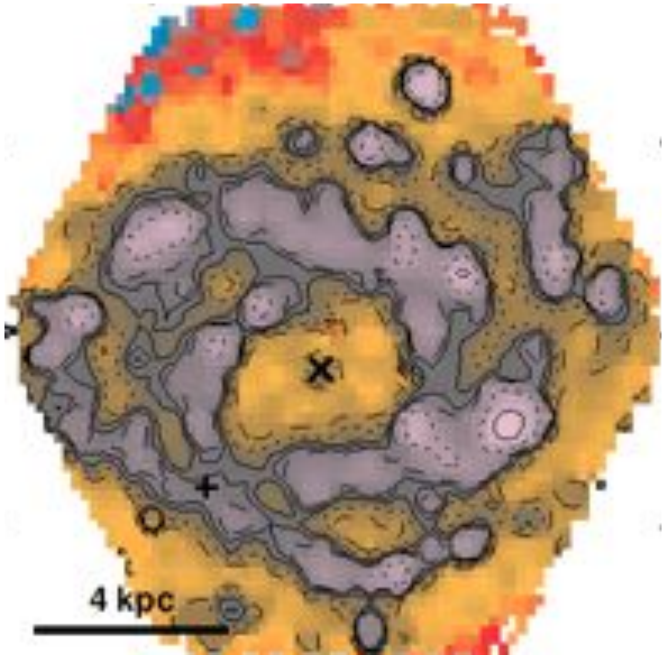
INTEGRAL FIELD SPECTROSCOPY OF SUPERNOVA HOST GALAXIES

Pinheiro Furtado et al. 1842

Gaudi et al. 1906



The CALIFA collaboration 2014

TÉCNICO LISBOA

centra multidisciplinary centre for astrophysics

Lluis Galbany

Fondecyt Fellow

CENTRA, Portugal ⟶ MAS/DAS, Chile

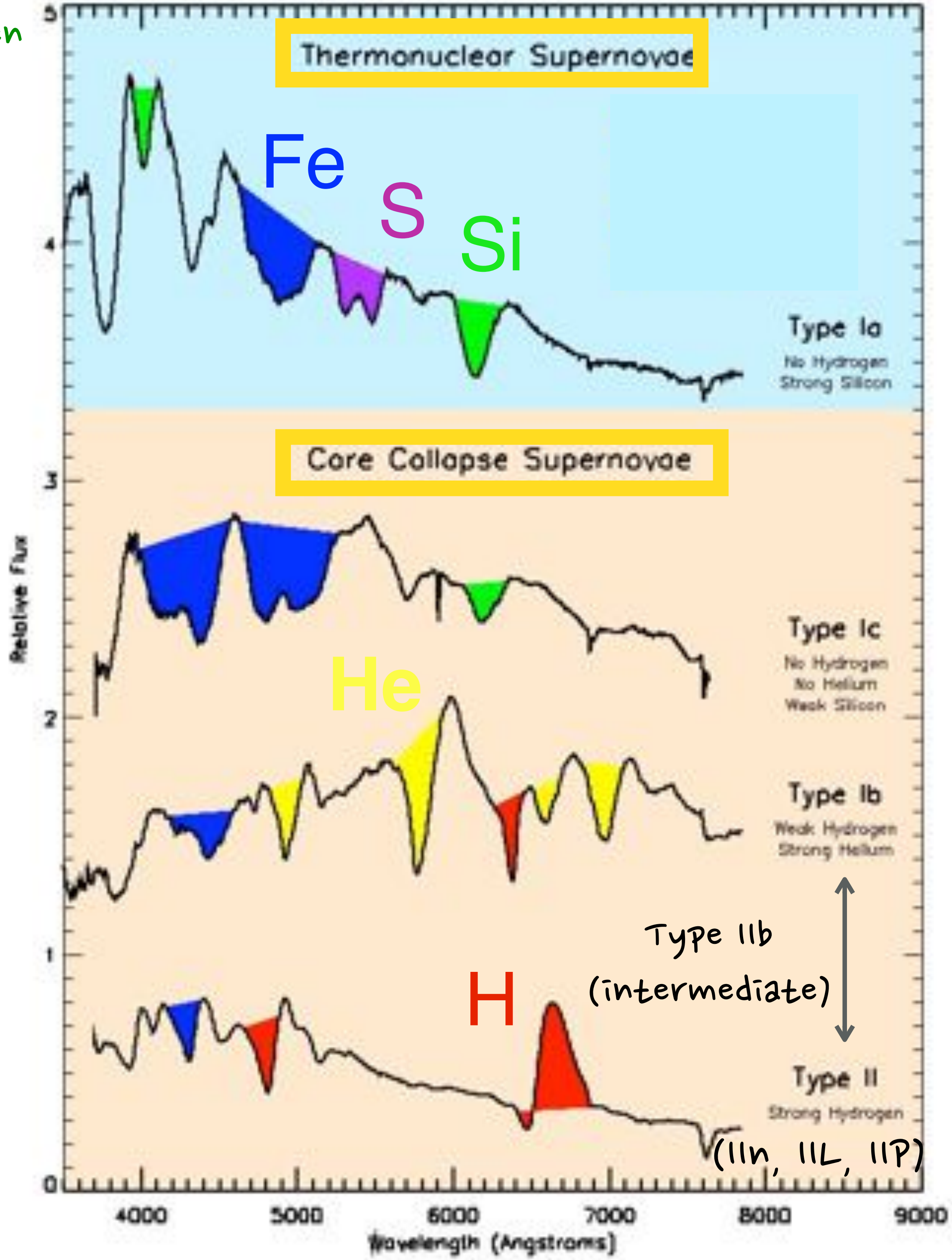
FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE

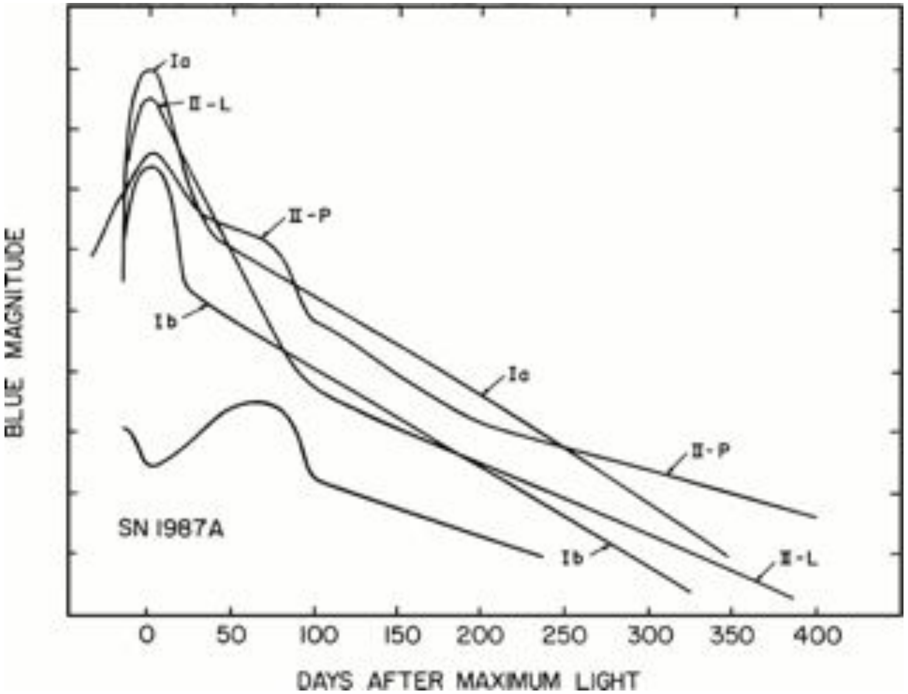
MILLENNIUM INSTITUTE OF ASTROPHYSICS

Guillermo Haro 2014 – INAOE, Puebla, 1 September 2014

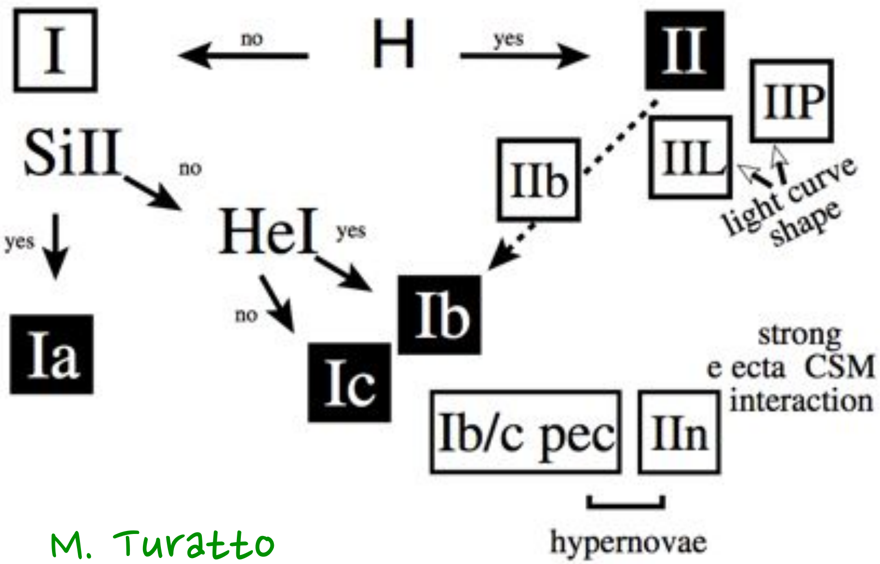
SN zoo

D. Kasen





Wheeler 1990



M. Turatto

SN zoo

from K.W. Weiler

CO white dwarfs in binary systems
accreting mass from a companion

2 scenarios: - single degenerate
(WD + massive star)

- double degenerate (2 WD)

Homogeneous brightness ⟶ cosmology

Massive stars (8 to 30 Msun)

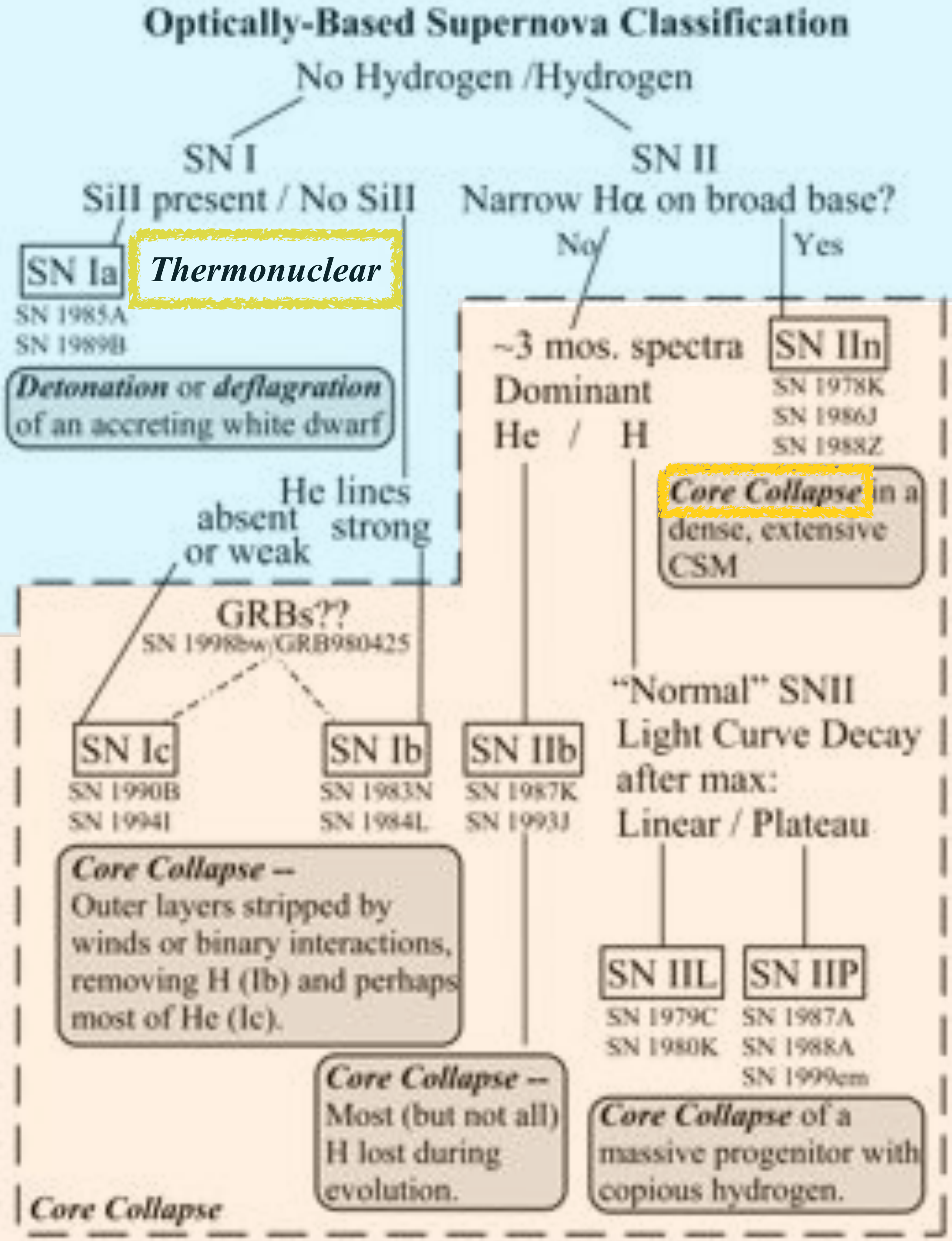
Differences depending on progenitor
mass loss before explosion

Mass loss ↑

- Ic lose both H and He envelopes
- Ib lose H envelope
- IIb intermediate between II and Ib
- II retain external layers (H and He)

2 paths: - single massive stars + winds

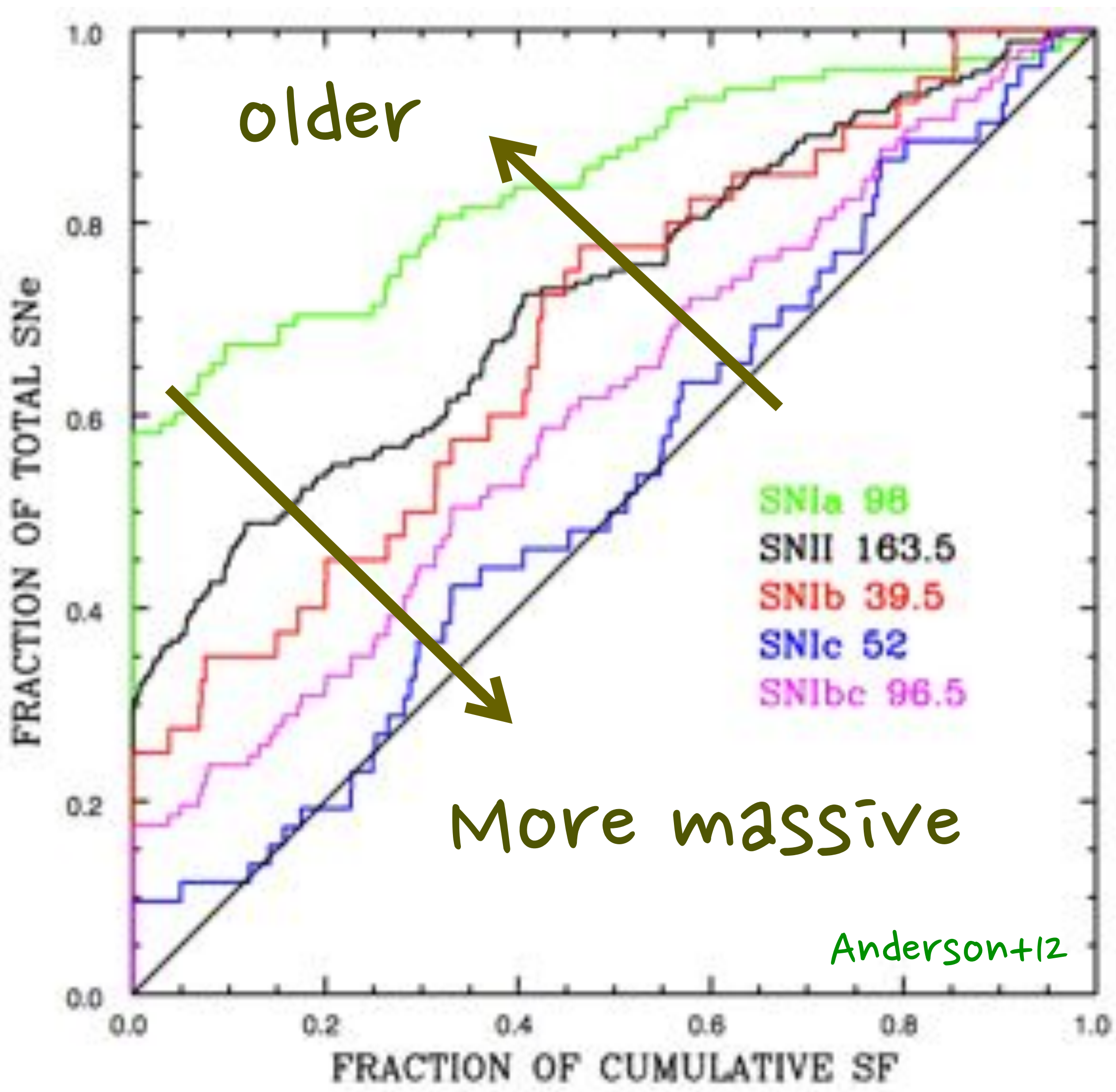
- binary systems transferring mass



progenitor constraints

Few ccSNe and no SNe Ia direct progenitor detection (e.g. Smartt+09)

Alternative methods to constrain progenitor properties: ENVIRONMENT

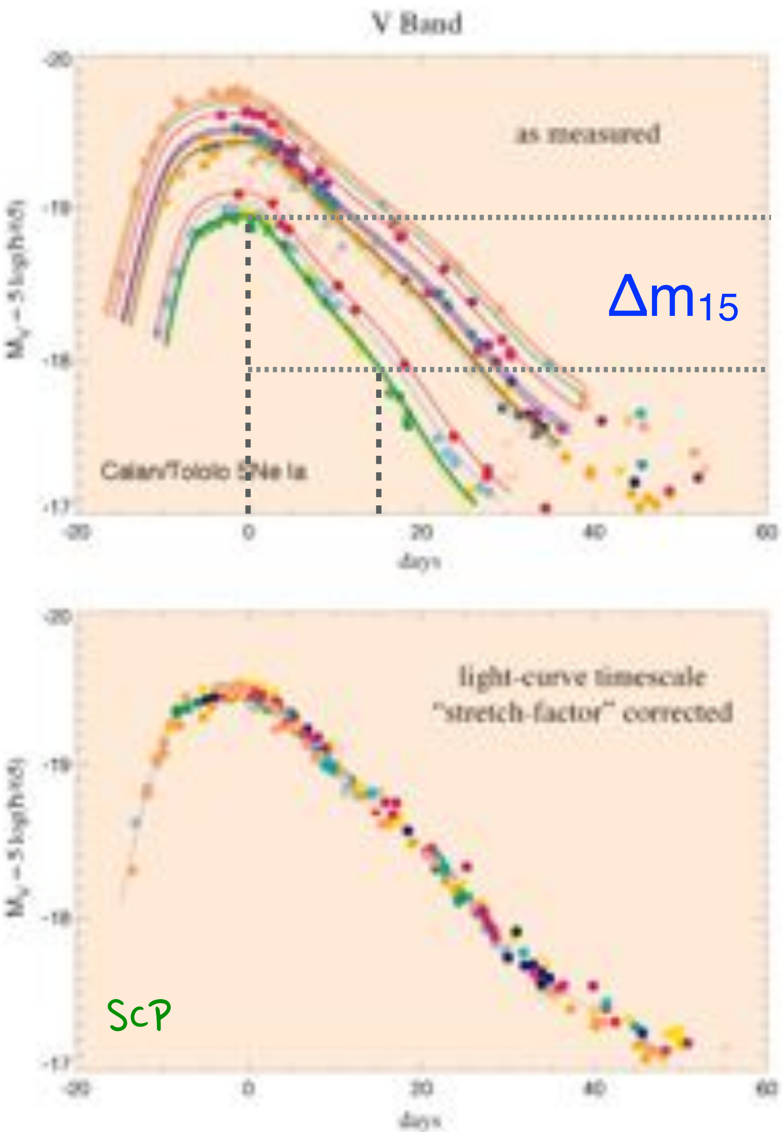


cumulative distributions of local star-formation at SN position for several SN types from Hα imaging

Assuming that all the stars in a cluster have similar ages, more association to the star-forming region can be understood as young and more massive star

More massive stars have shorter lifetimes (age) and therefore have less time to move away from the star-forming regions

SN Ia cosmology

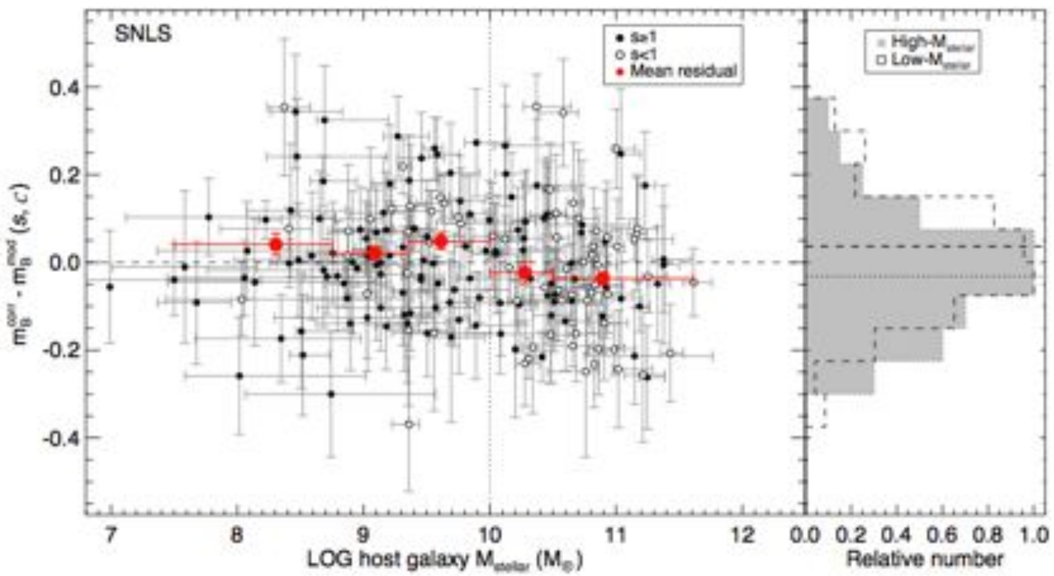


Empirical relation enables the standardization

Scatter ~0.11 mag ⟶ Precision ~5-7%

Environmental effects arise as a source of systematic errors

Sullivan+10

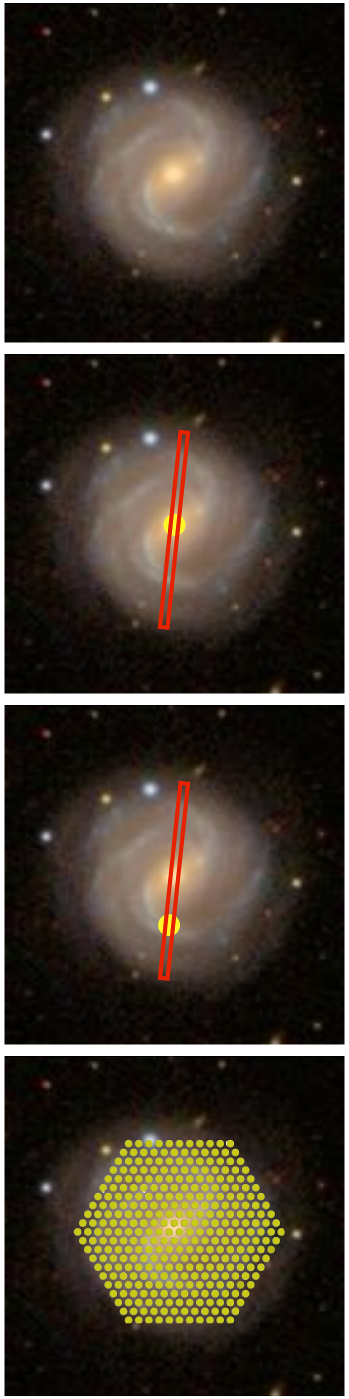


SN environmental studies

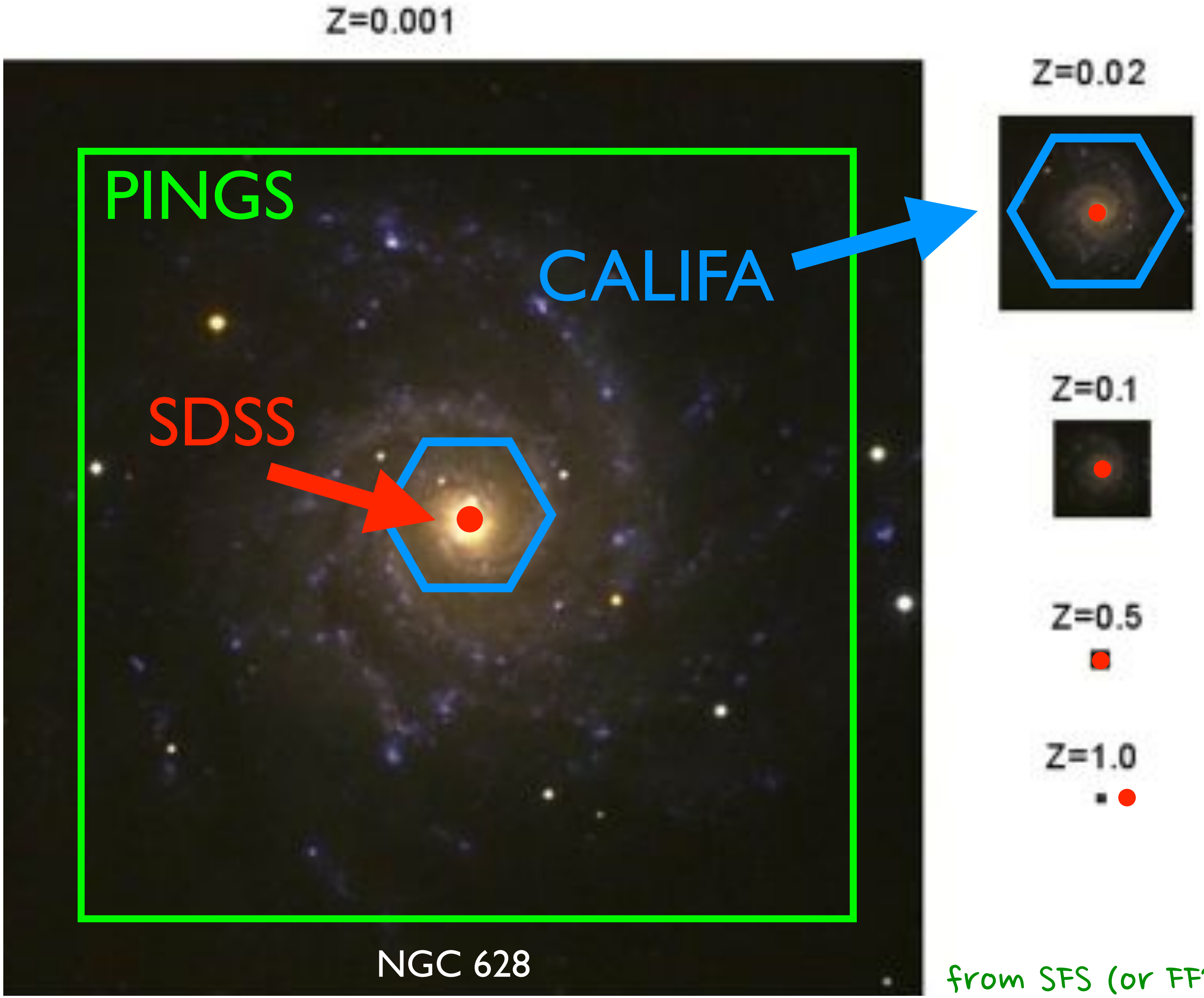
- Global properties
  - photometry / imaging
    (Hamuy+96, Sullivan+10, Lampeitl+10, Anderson+09...)
  - single-aperture /long-slit spectroscopy (@galaxy core)
    (Prieto+08, D'Andrea+12, Anderson+12...)

- Local properties
  - central values + gradients
    (Boissier+09, Galbany+12...)
  - single-aperture / long-slit spectroscopy (@SN position)
    (Anderson+10&12, Modjaz+11...)

- Integral Field Spectroscopy
  (Stanishev+12, Kuncarayakti+13ab, Galbany+14)

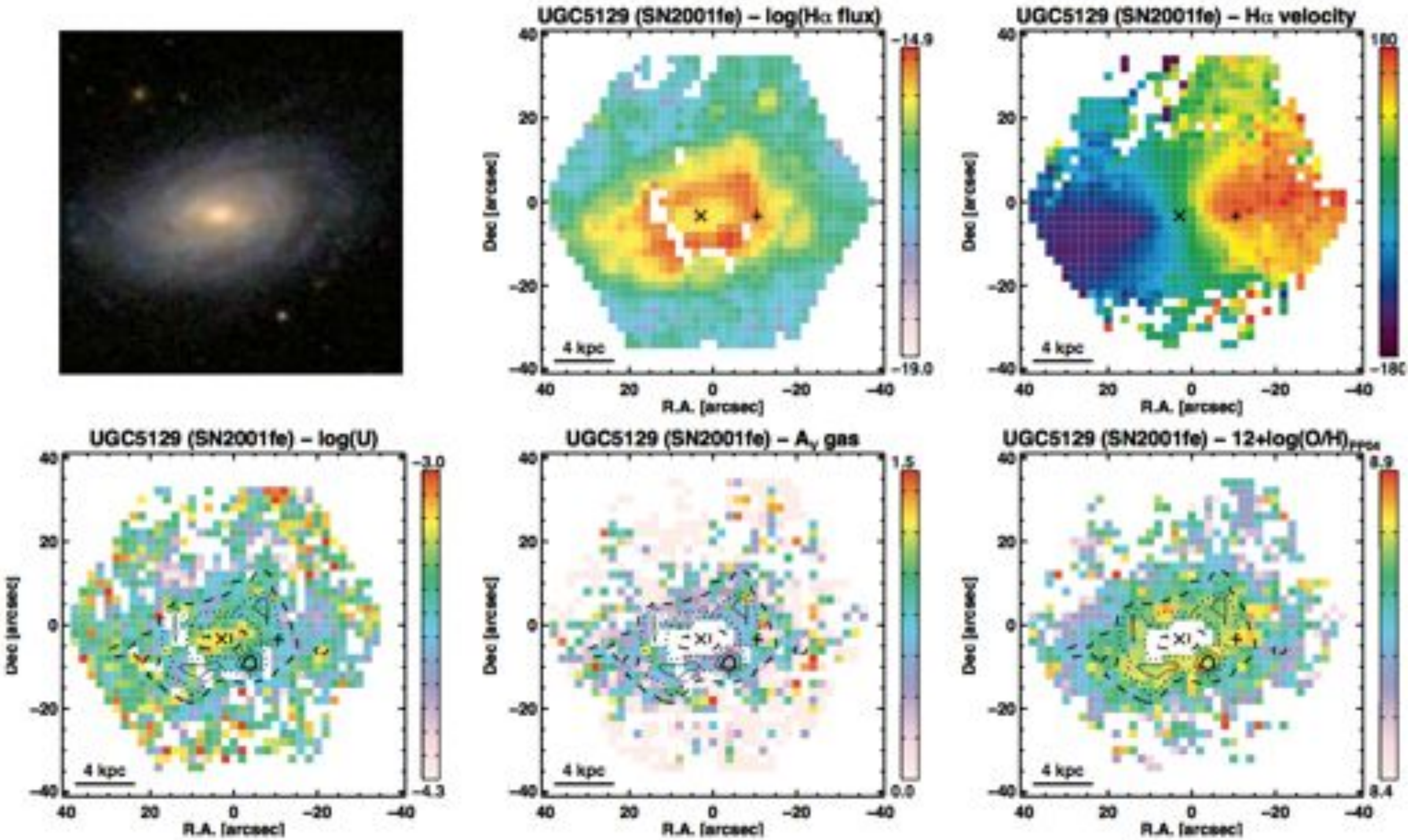


why nearby? the FoV issue



from SFS (or FFRO?)...

SN Ia host galaxies with IFU



6 SNe Ia host galaxies (z 0.01–0.03) with PMAS/PPAK

Stanishev+12

SN Ia host galaxies with IFS

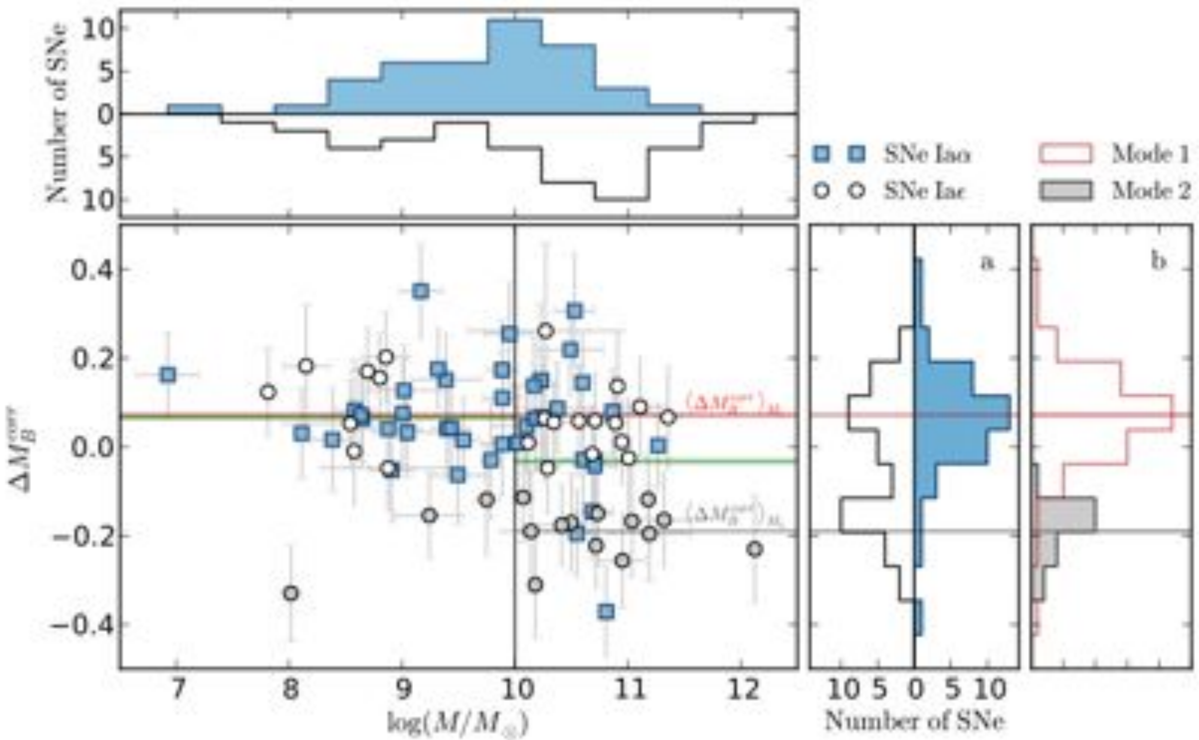
SNfactory

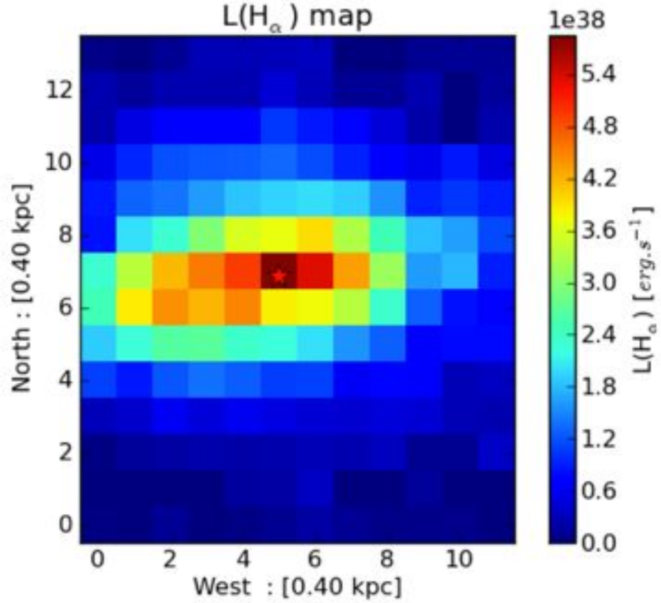
SNIFS

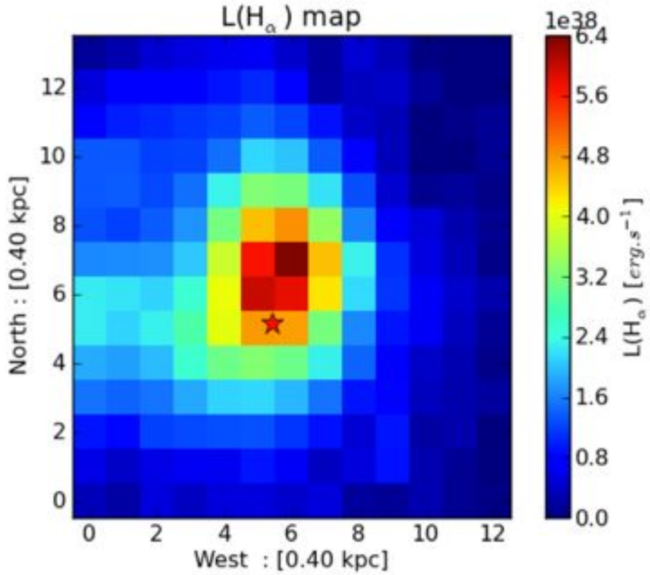
82 SNe, z 0.03-0.09

Studied the mass step function (~Sullivan plot)

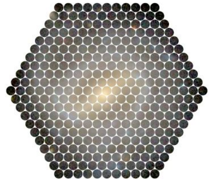
Only use SNe Ia in SF galaxies







Rigault+13

IFS of SN host galaxies in 

Nearby supernova host galaxies from the CALIFA Survey:

I. Sample, data analysis, and correlation to star-forming regions

Submitted to A&A

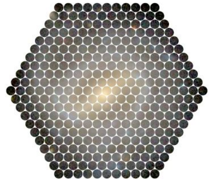
L. Galbany[1,2,3], V. Stanishev[1], A. M. Mourão[1], M. Rodrigues[4,5], H. Flores[5], R. García-Benito[6], D. Mast[7], M. A. Mendoza[6], S. F. Sánchez[8], C. Badenes[9], J. Barrera-Ballesteros[10,11], J. Bland-Hawthorn[12], J. Falcón-Barroso[10,11], B. García-Lorenzo[10,11], J. M. Gomes[12], R. M. González Delgado[6], C. Kehrig[6], M. Lyubenova[13], A. R. López-Sánchez[14,15], A. de Lorenzo-Cáceres[16], R. A. Marino[17], S. Meidt[13], M. Mollá[18], P. Papaderos[12], M. A. Pérez-Torres[6,19,20], F. F. Rosales-Ortega[21], G. van de Ven[13], and the CALIFA Collaboration

Nearby supernova host galaxies from the CALIFA Survey:

II. SN environmental metalicity

in (adv.) prep.

L. Galbany[1,2,3], V. Stanishev[1], A. M. Mourão[1], M. Rodrigues[4,5], H. Flores[5], R. García-Benito[6], D. Mast[7], M. A. Mendoza[6], S. F. Sánchez[8], C. Badenes[9], J. Barrera-Ballesteros[10,11], J. Bland-Hawthorn[12], J. Falcón-Barroso[10,11], B. García-Lorenzo[10,11], J. M. Gomes[12], R. M. González Delgado[6], C. Kehrig[6], M. Lyubenova[13], A. R. López-Sánchez[14,15], A. de Lorenzo-Cáceres[16], R. A. Marino[17], S. Meidt[13], M. Mollá[18], P. Papaderos[12], M. A. Pérez-Torres[6,19,20], F. F. Rosales-Ortega[21], G. van de Ven[13], and the CALIFA Collaboration

IFS of SN host galaxies in 

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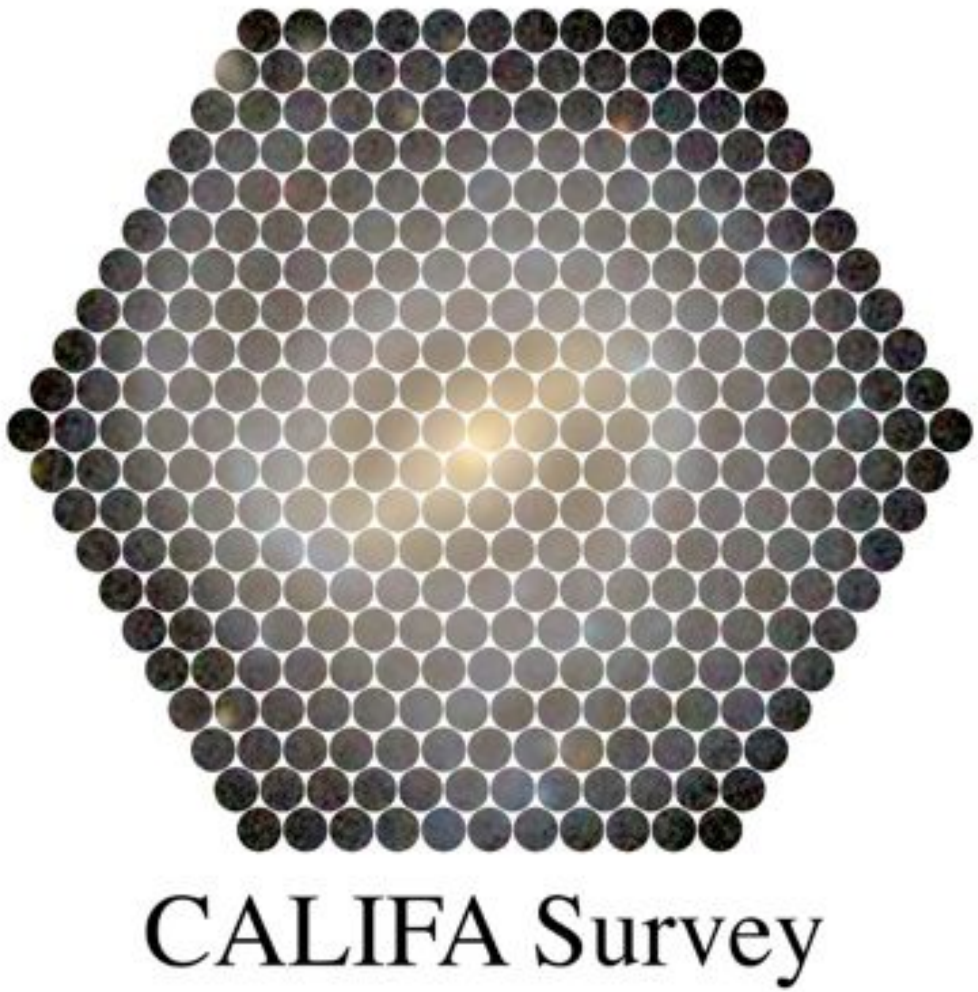
Calar Alto Legacy Integral Field Area

Sanchez+12



- survey of ~600 galaxies of all types at z=0.005 to 0.03
- diameter selected from SDSS DR7, $45 < D_{25} < 80$, to fit in the IFU FOV

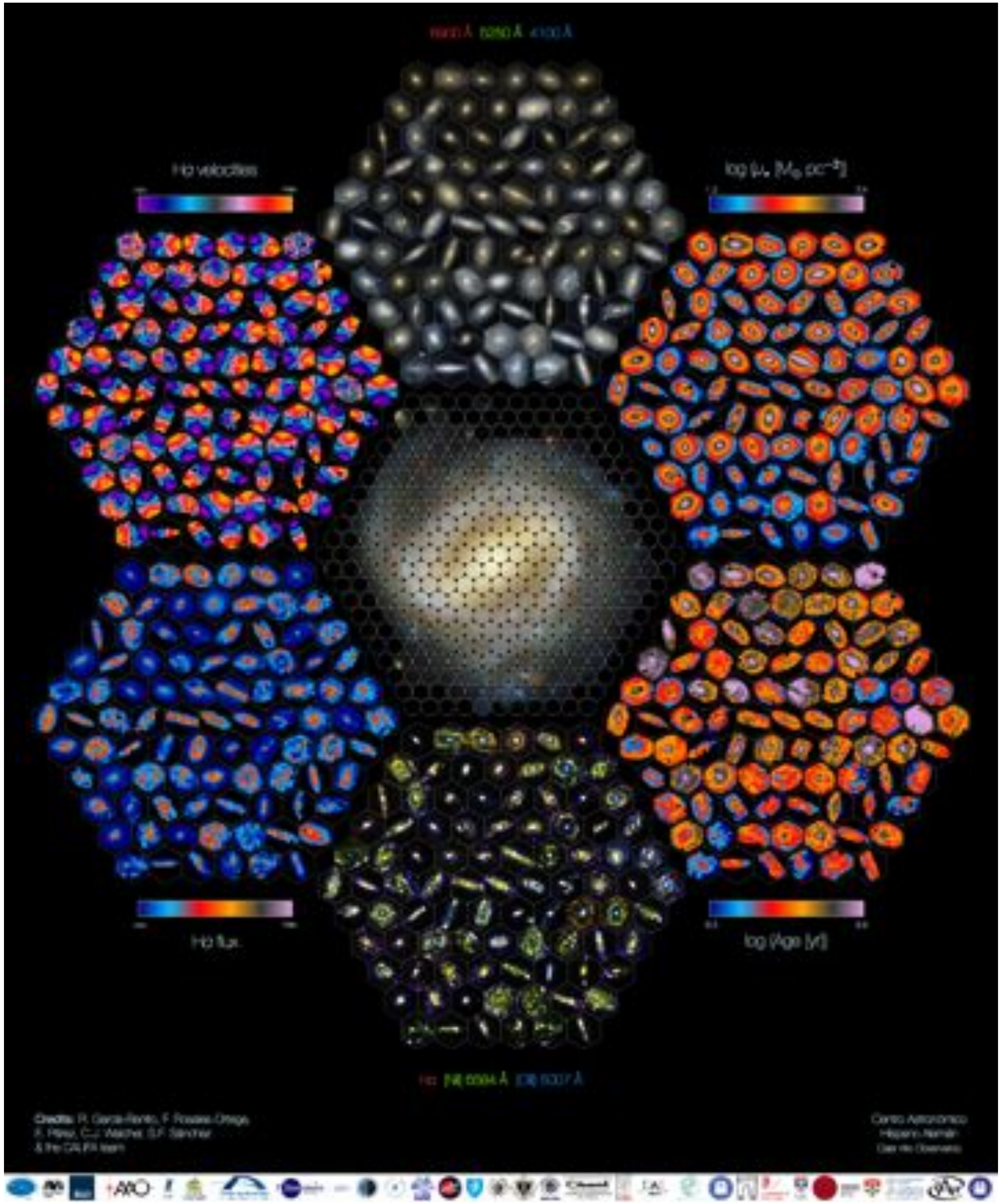
  CALIFA mother sample: 939 galaxies
- IFS using PPAK @ 3.5m CAHA
  - 2 setups: mid (V500) and high-res (V1200)
  - Spectral coverage [3700-7000 A]
  - Spatial resolution ~1 arcsec
- 250 dark nights over 3 years
- ~3000 spectra per galaxy
- data will freely distributed to the community.

DR1 (100 galaxies), Husemann+13

DR2 (200 galaxies), Garcia-Benito in prep.

calar Alto Legacy Integral Field Area

Sanchez+12



- survey of ~600 galaxies of all types at z=0.005 to 0.03
- diameter selected from SDSS DR7, 45 < D_{25} < 80, to fit in the IFU FOV

  cALIFA mother sample: 939 galaxies

- IFS using PPAK @ 3.5m CAHA

  - 2 setups: mid (V500) and high-res (V1200)
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DR1 (100 galaxies), Husemann+13

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sample selection

cross-check SNe IAU list with CALIFA galaxies (by coord.)

~450 galaxies observed so far (at least with one grating)

65 hosted 73 SNe (6 with 2 SNe, 1 with 3 SNe)

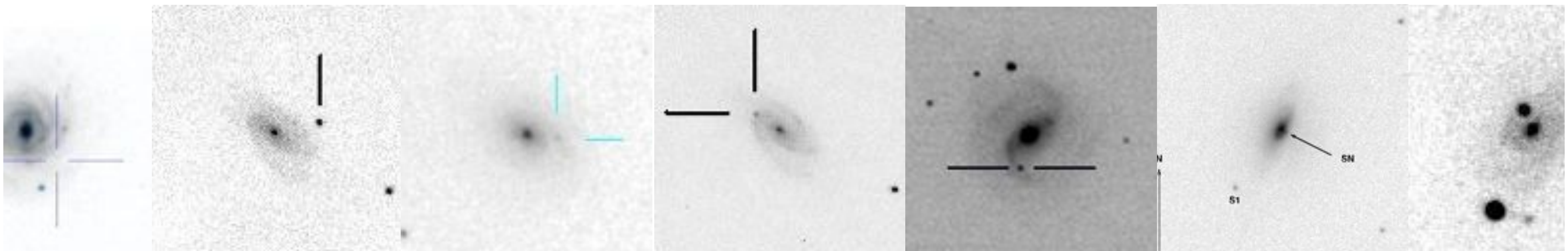
58 SNe in the field of view: 22 II, 13 Ibc/IIb, 23 Ia

Previous studies (SAME INSTRUMENT!!)

4 feasibility study for CALIFA, Sanchez+12
8 PINGS Survey, Rosales-Ortega+10
5 SNIa hosts, Stanishev+12
NGC5668 and NGC3982, Marino+12 & in prep.
12 galaxies, CALIFA extensions

37 SNe: 11 II, 7 Ibc/IIb, 19 Ia

95 SNe: 33 II, 20 Ibc, 42 Ia

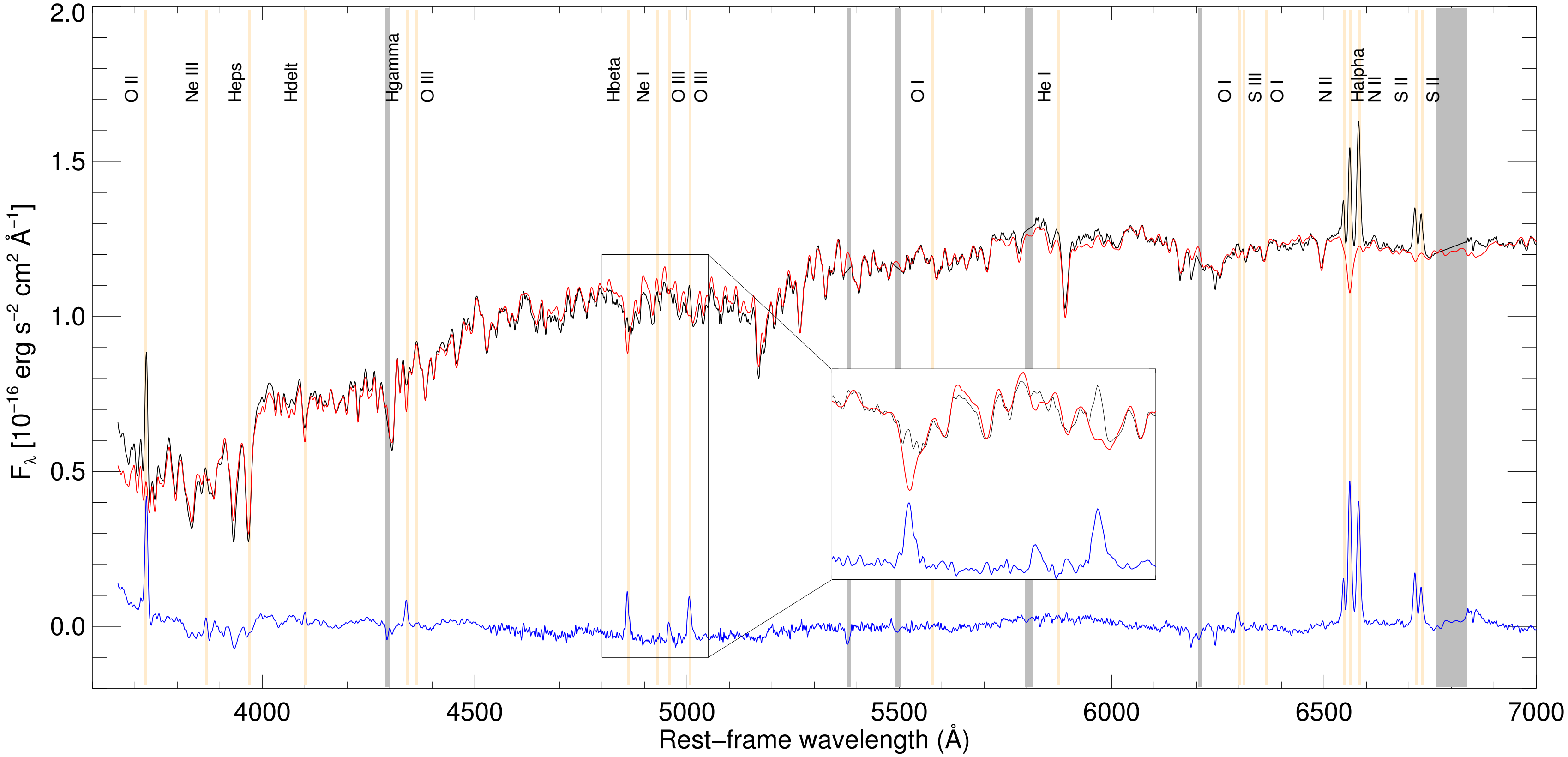


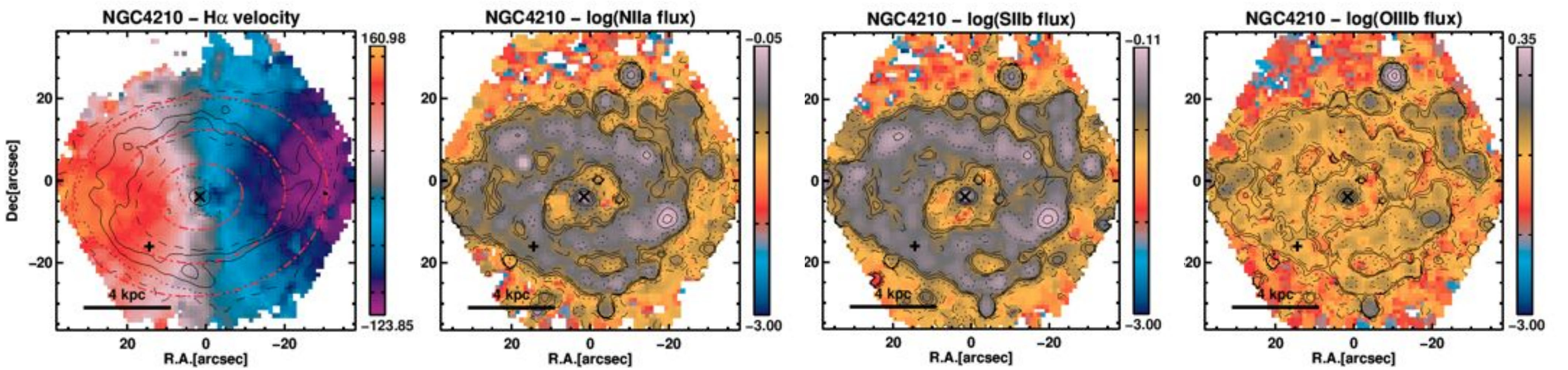
STARLIGHT

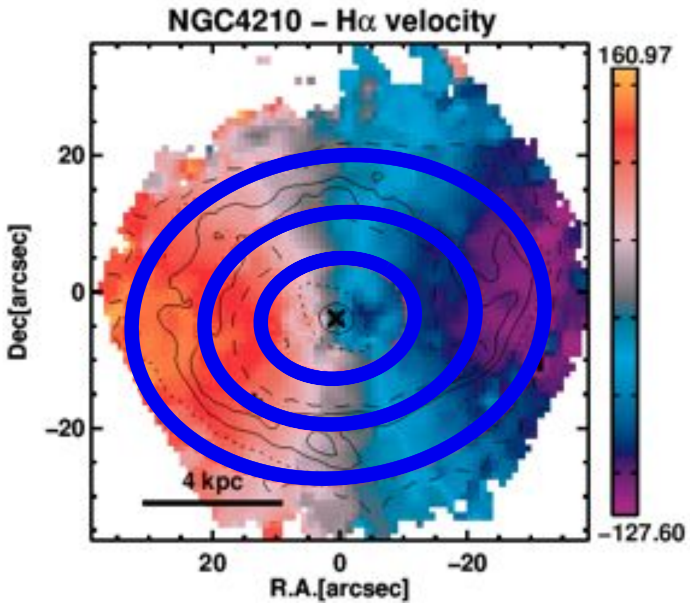
Cid Fernandes et al. 2005

CB07: 17 Ages 10^6 to $1.8\ 10^{10}$ $M_\odot$

4 metallicities 0.004, 0.05, 0.2, 2.5 $Z_\odot$







kinemetry

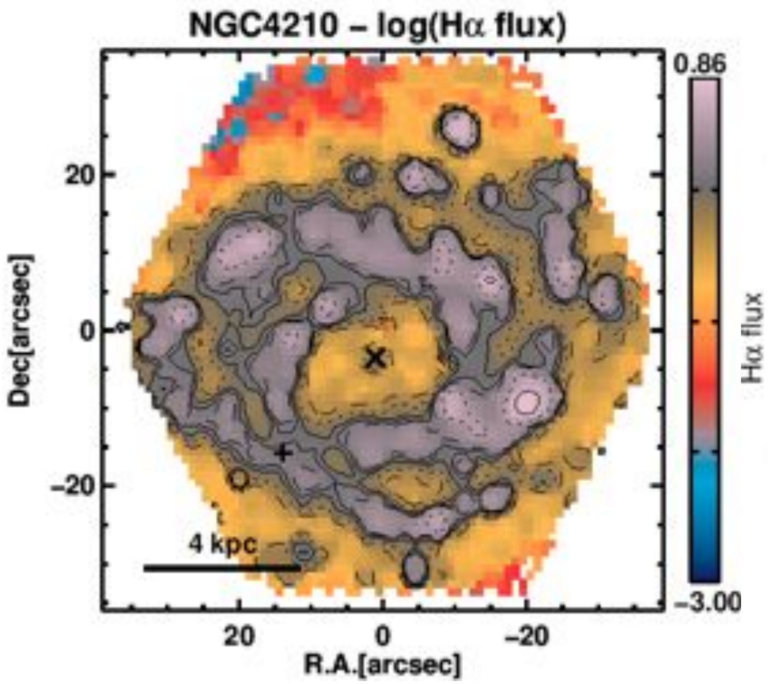
fit ellipses using Krajnovic et al. 2006

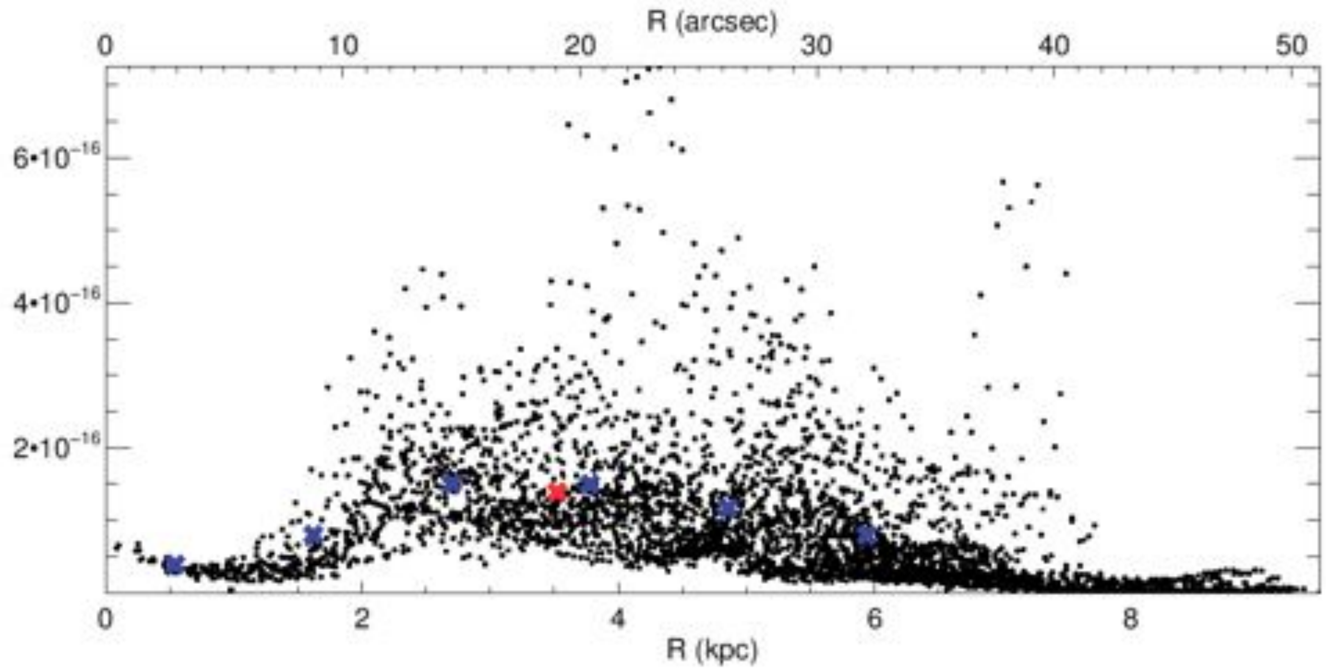
deprojection

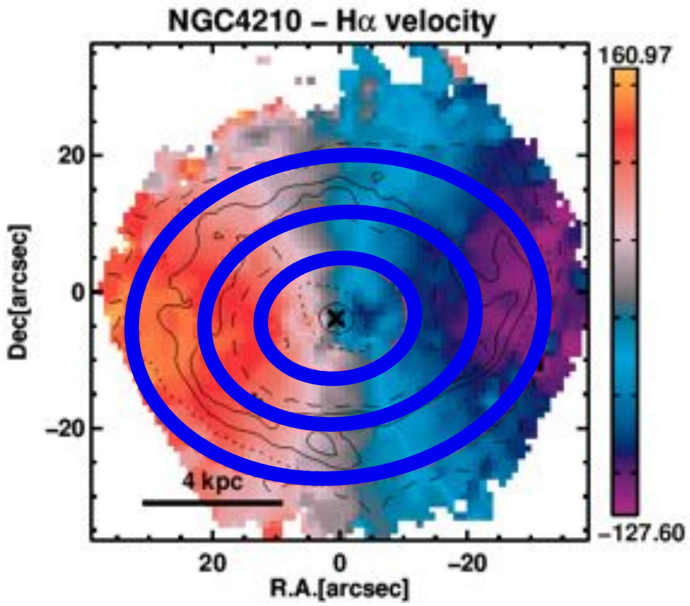
measure distances in the galactic plane

voronoi (spatial) binning

increase S/N in the outskirts







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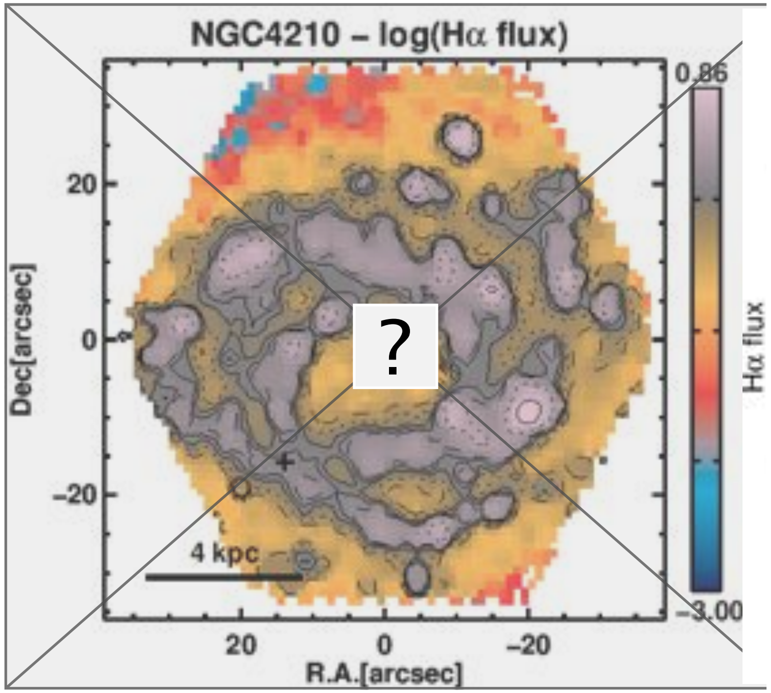
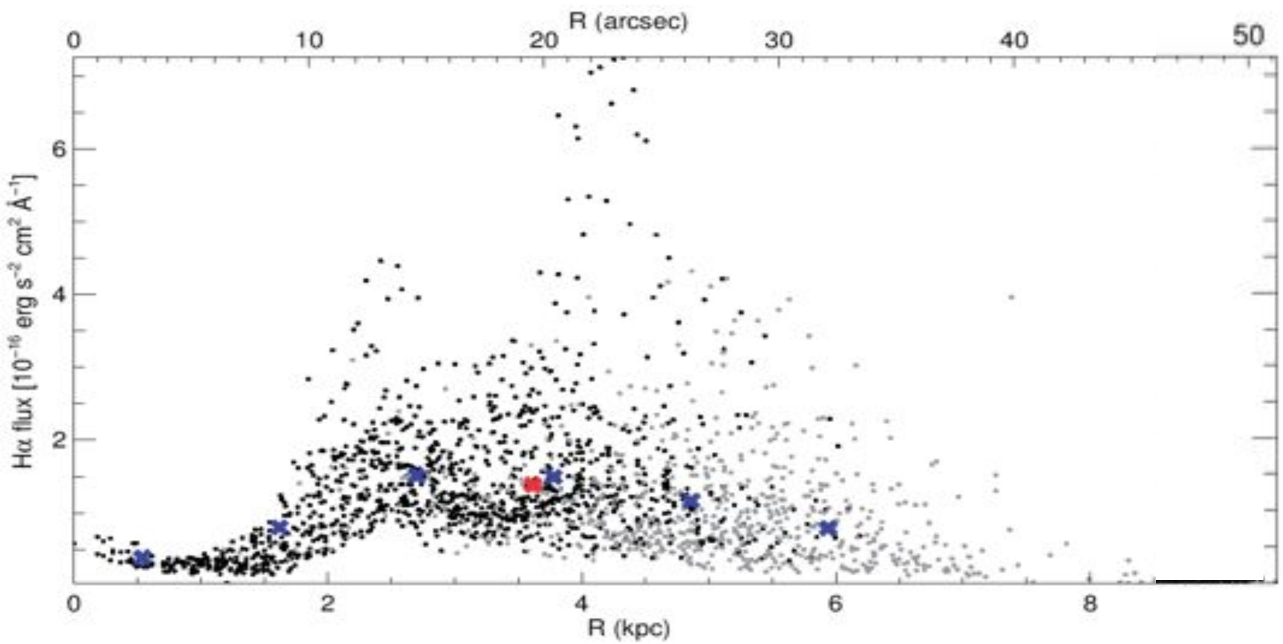




GCDs

distance as a proxy of local metallicity, assuming the presence of gradients (Galbany+12)

comparison with ASIAGO SN catalogue

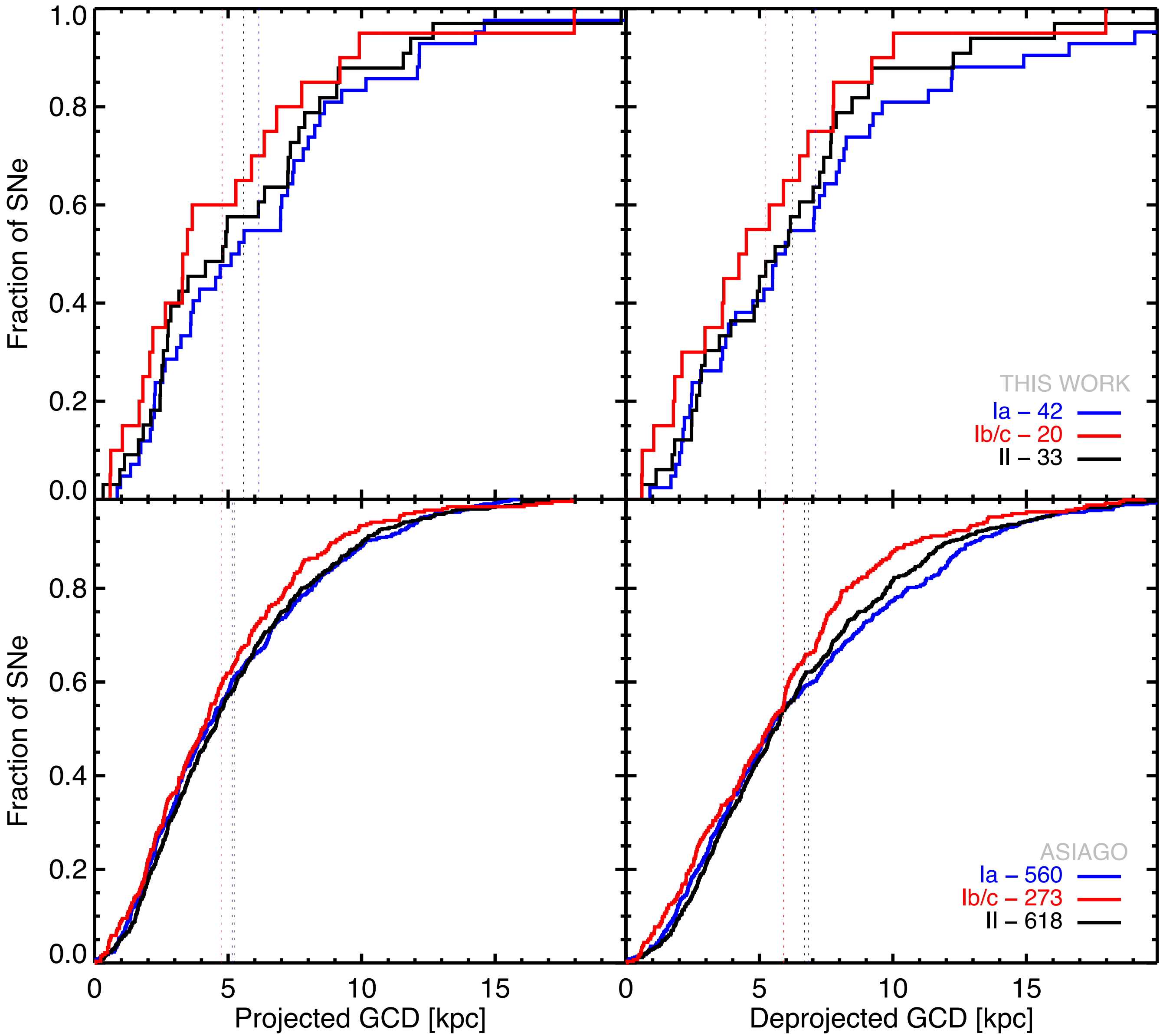
Ibc/IIb closer to the galaxy core

Ia found further

Ibc/IIb would explode in metal-richer environments since they explode closer to the center of the galaxy

Projected GCD

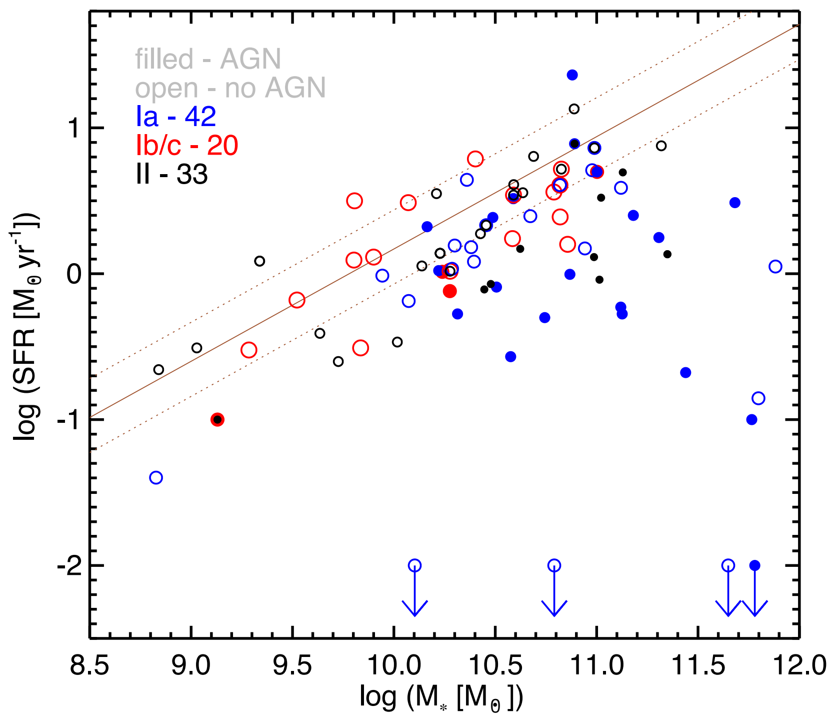
Deprojected GCD (using Hα velocity maps)

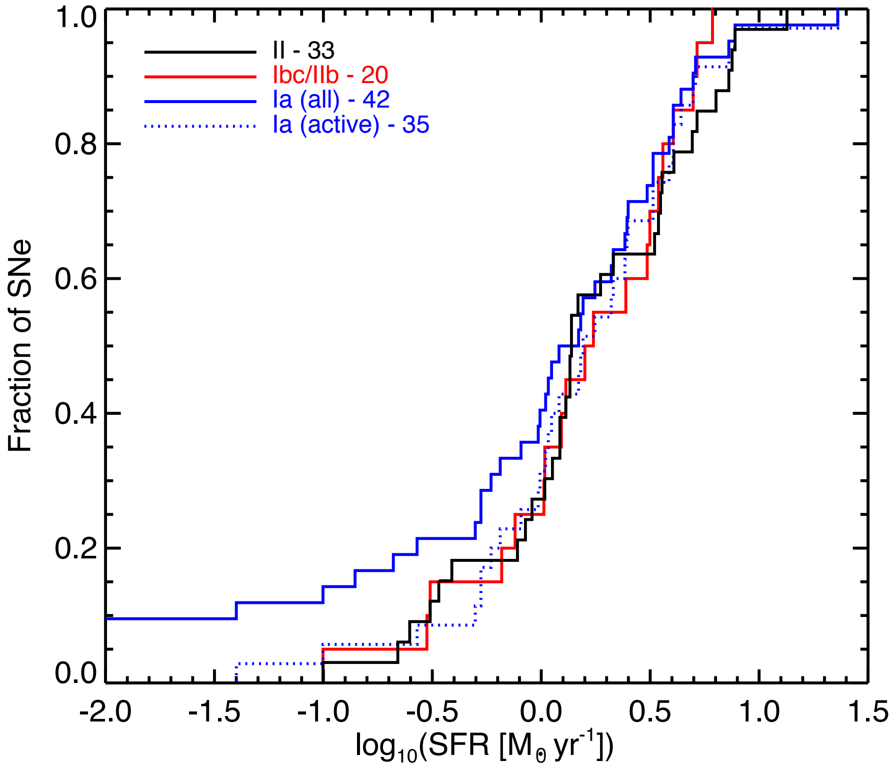


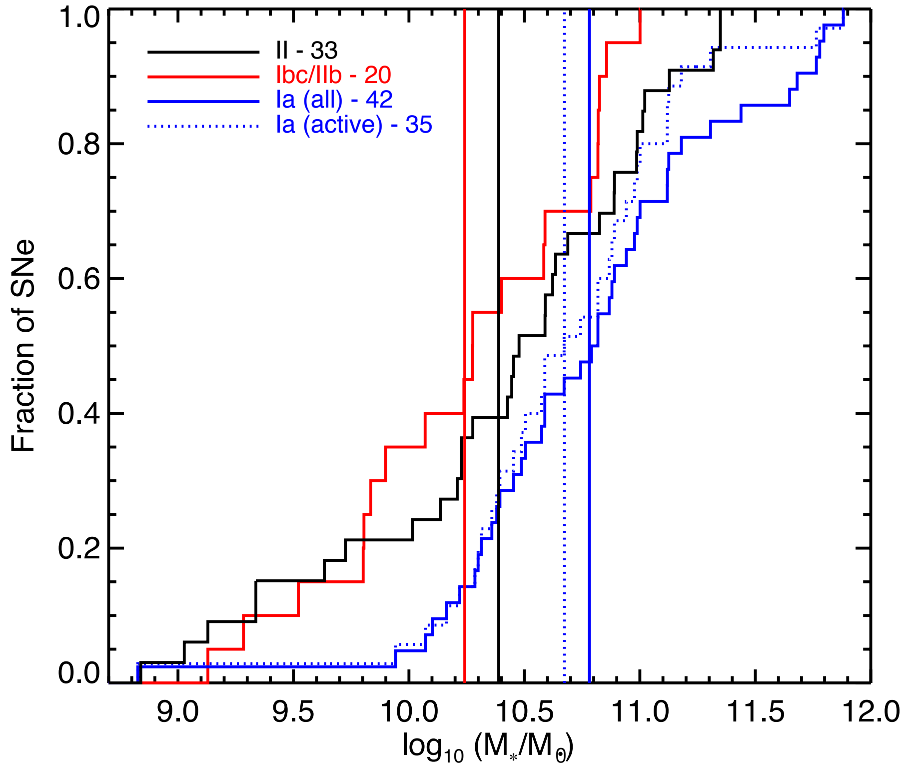
global host galaxy properties

construction of integrated spectra

- on-going SFR from extinction-corrected Hα emission line maps
- galaxy total mass
- specific SFR (sSFR=SFR/mass)







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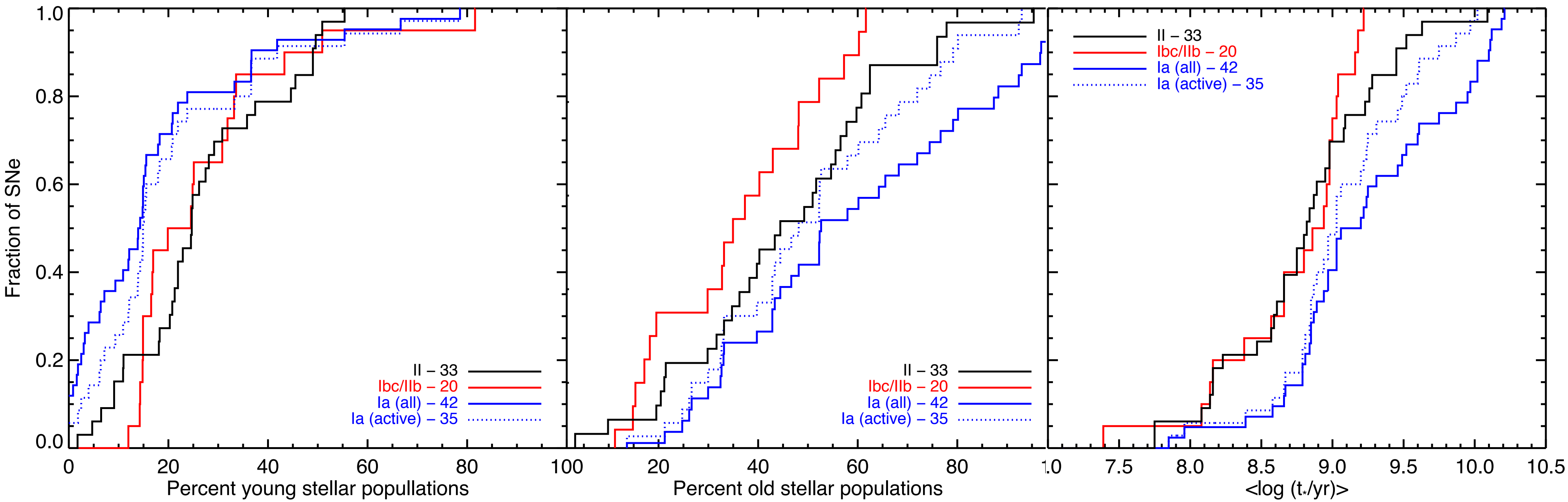
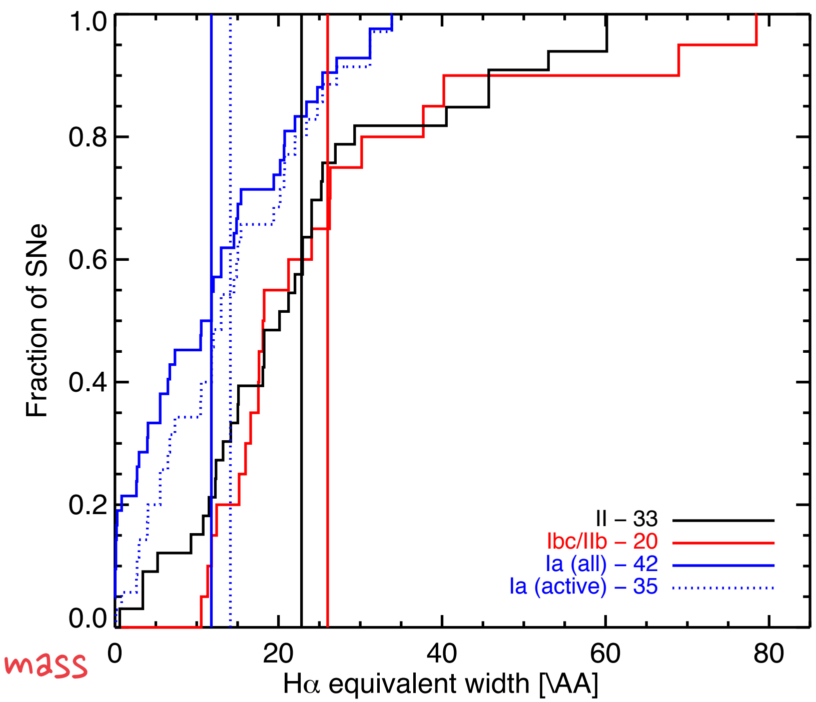




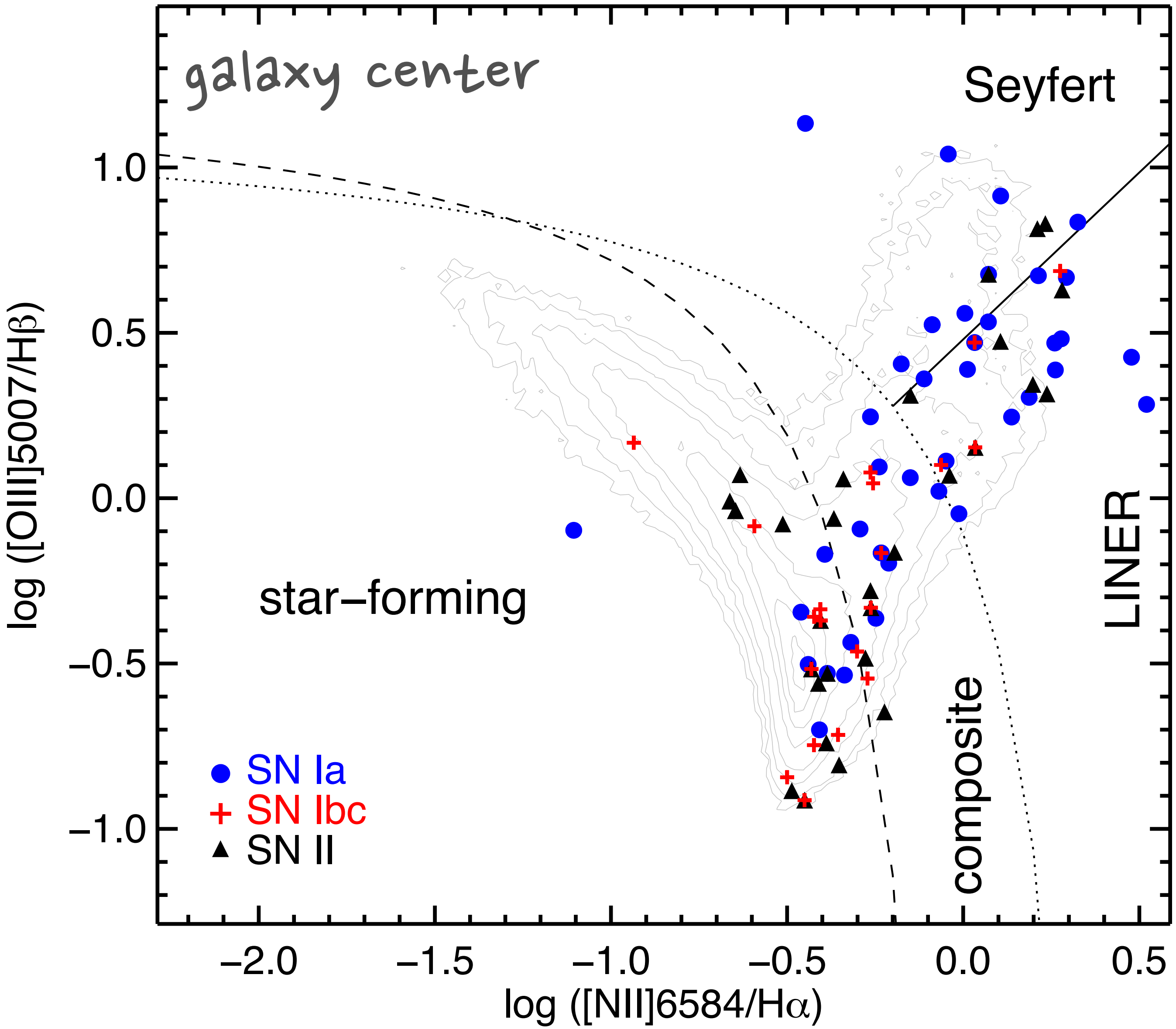
most of the stellar mass is locked in old stellar populations

- SFH: percent of stellar populations
- galaxy mean age
- Ha equivalent width as a tracer of young stellar population

$\sim \frac{\text{line}}{\text{cont.}}$ gas

stars ~> mass

global host galaxy properties - BPT diagram



Galaxy cores

50% Ia

30% II

20% Ibc/IIb

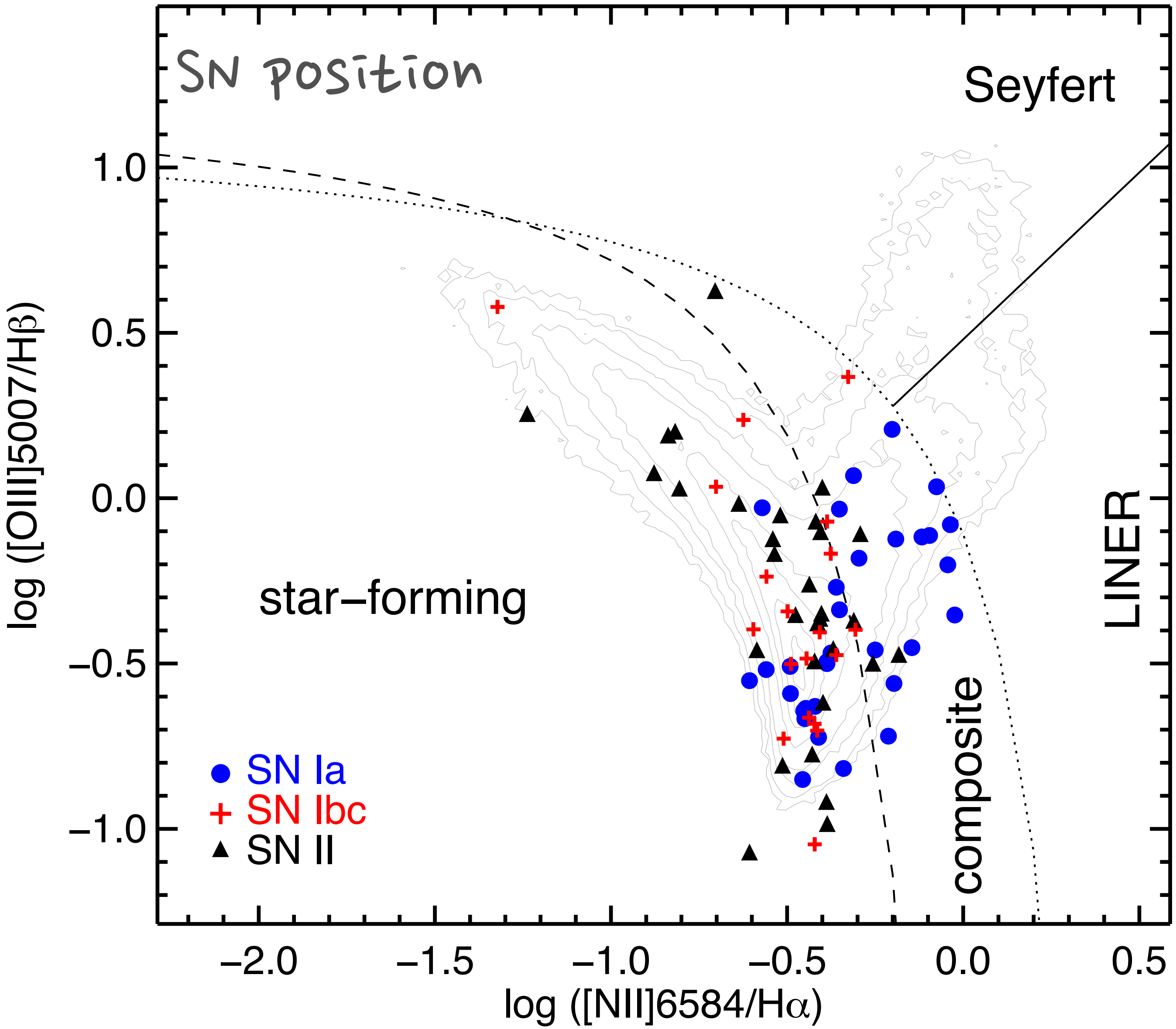
No SN in AGN

Rodrigues et al. in prep.

AGNs are diluted in integrated spectra

-> high-z

global host galaxy properties - BPT diagram



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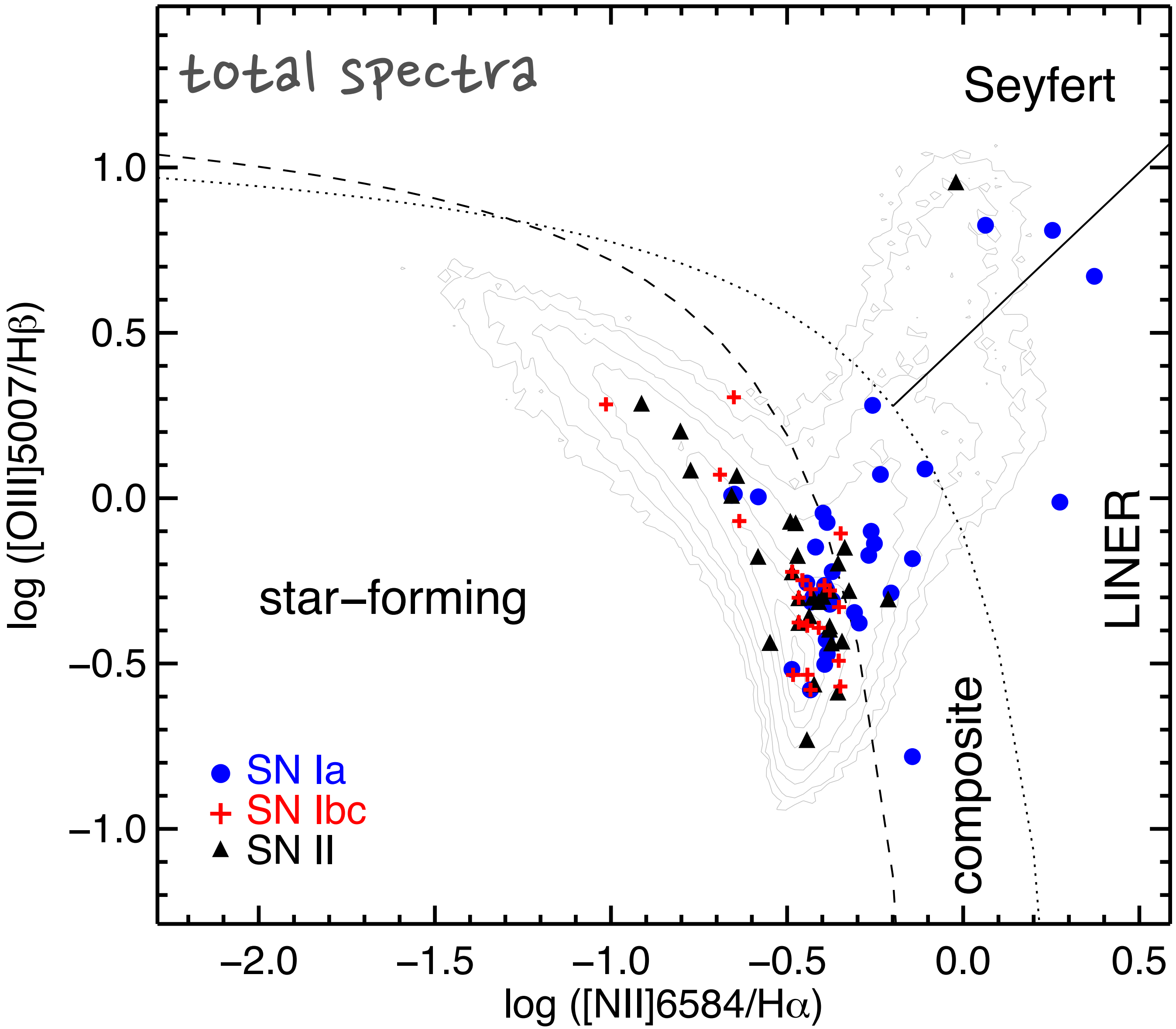

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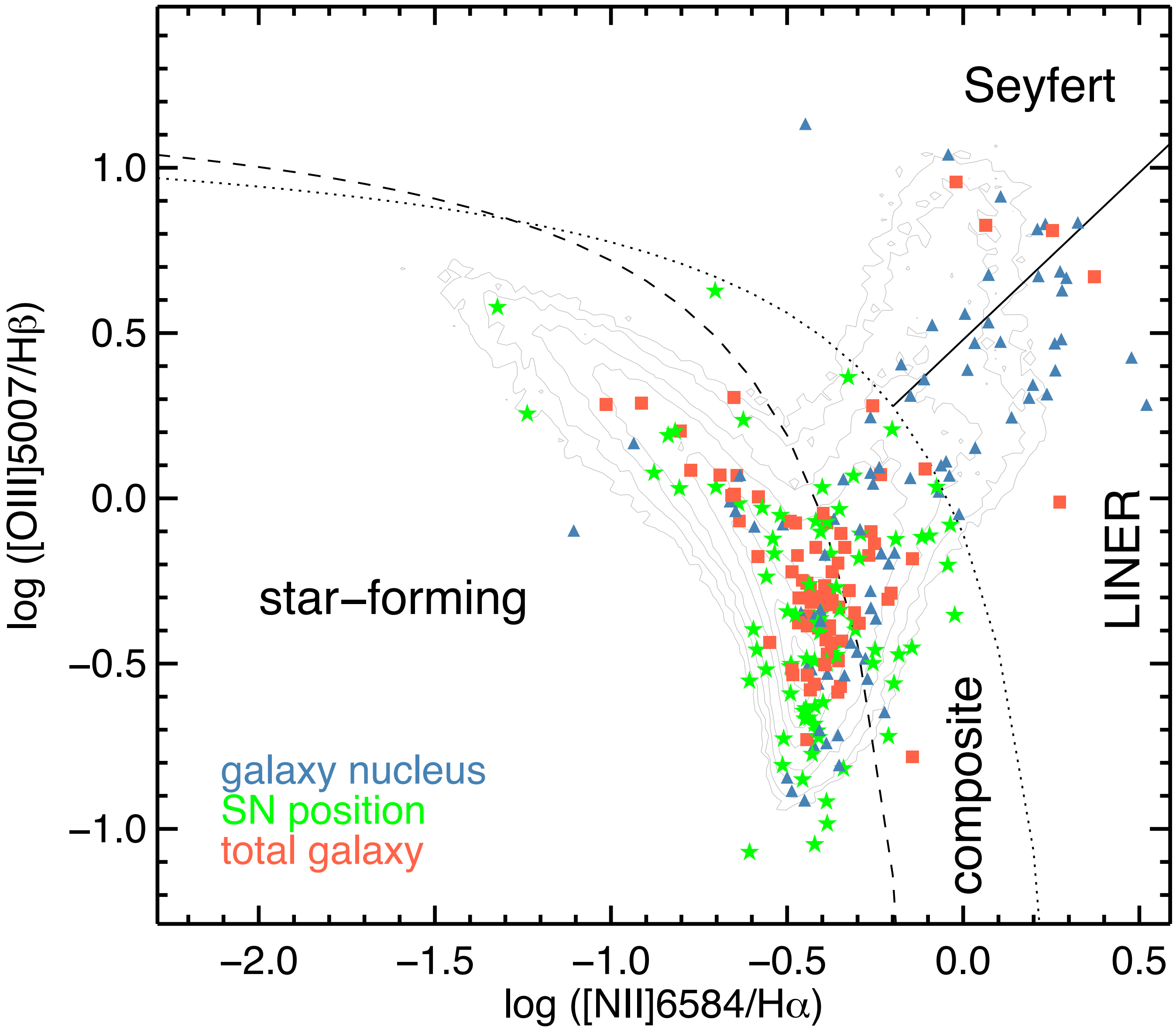

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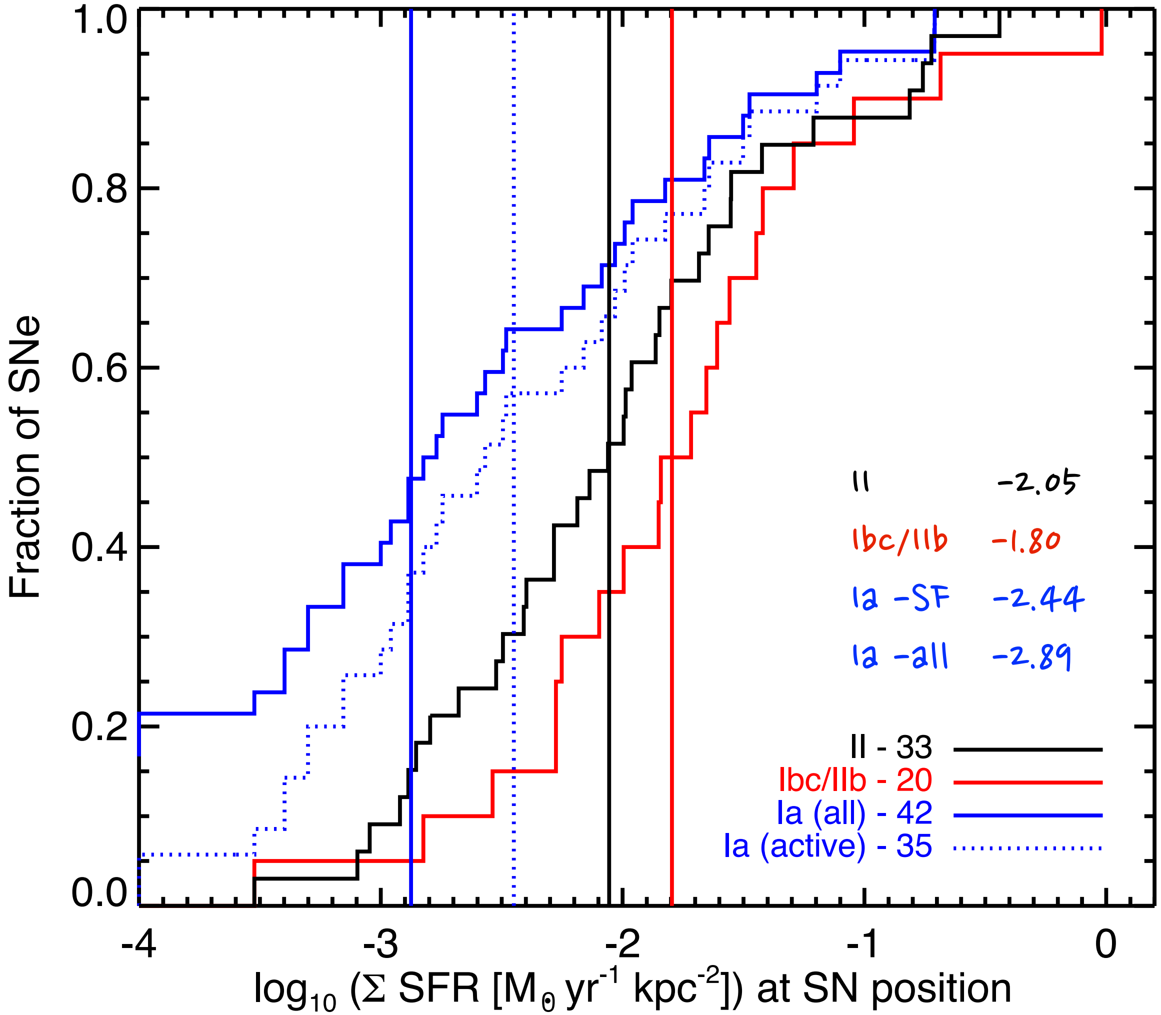
local host galaxy properties

star-formation rate density (ΣSRF=SFR/kpc^2)

SFR in the same neighboring region

accounting for inclination



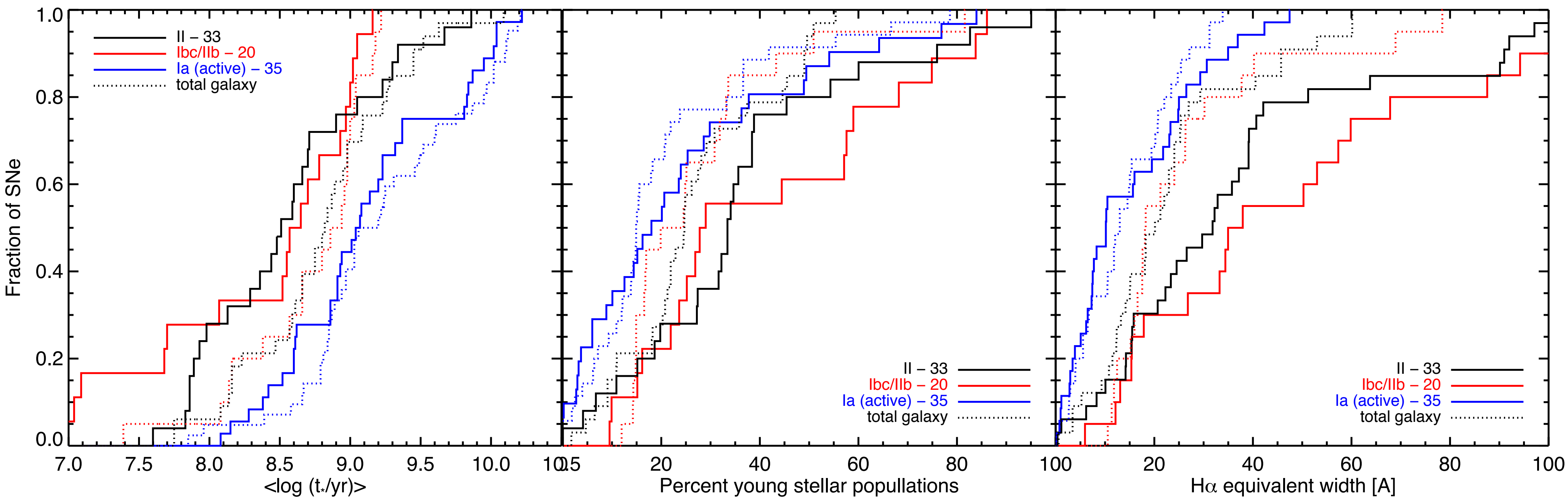
even in galaxies with similar SFR, Ibc/IIb tend to explode in higher ΣSRF regions than II and Ia

local host galaxy properties

1/2 slides!

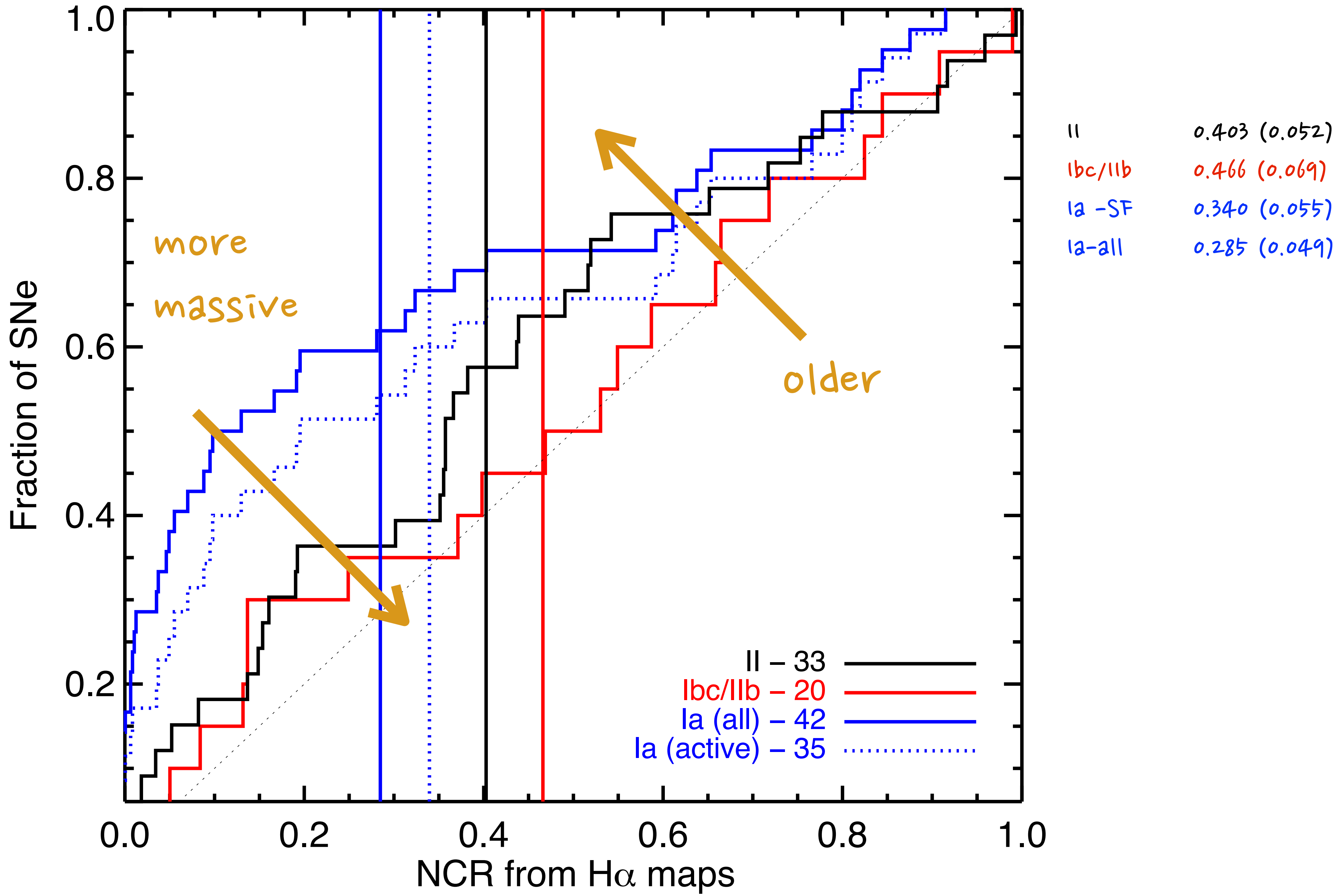
if T gt 12:05 then run

- stellar age
- percent of young stellar population
- Hα equivalent width

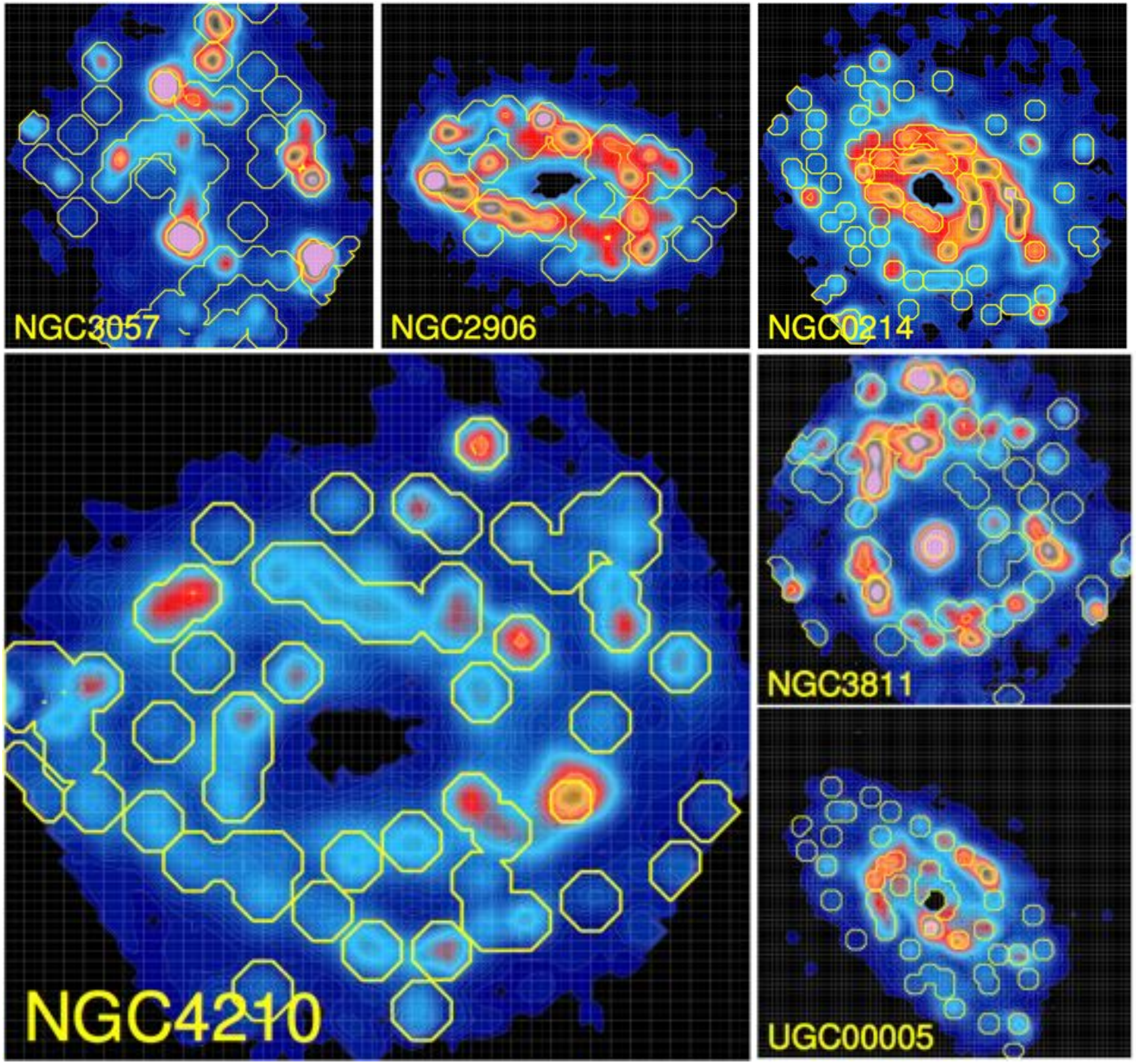


II	8.551 (0.106)	II	35,8 (4.1)	II	36.7 (5.0)
Ibc/IIb	8.356 (0.168)	Ibc/IIb	41.0 (5.8)	Ibc/IIb	57.3 (14.3)
Ia -SF	8.978 (0.084)	Ia -SF	24.1 (3.8)	Ia -SF	15.2 (2.2)
Ia-all	9.121 (0.091)	Ia-all	21.1 (3.5)		

local host galaxy properties - NCR



local host galaxy properties - star forming regions

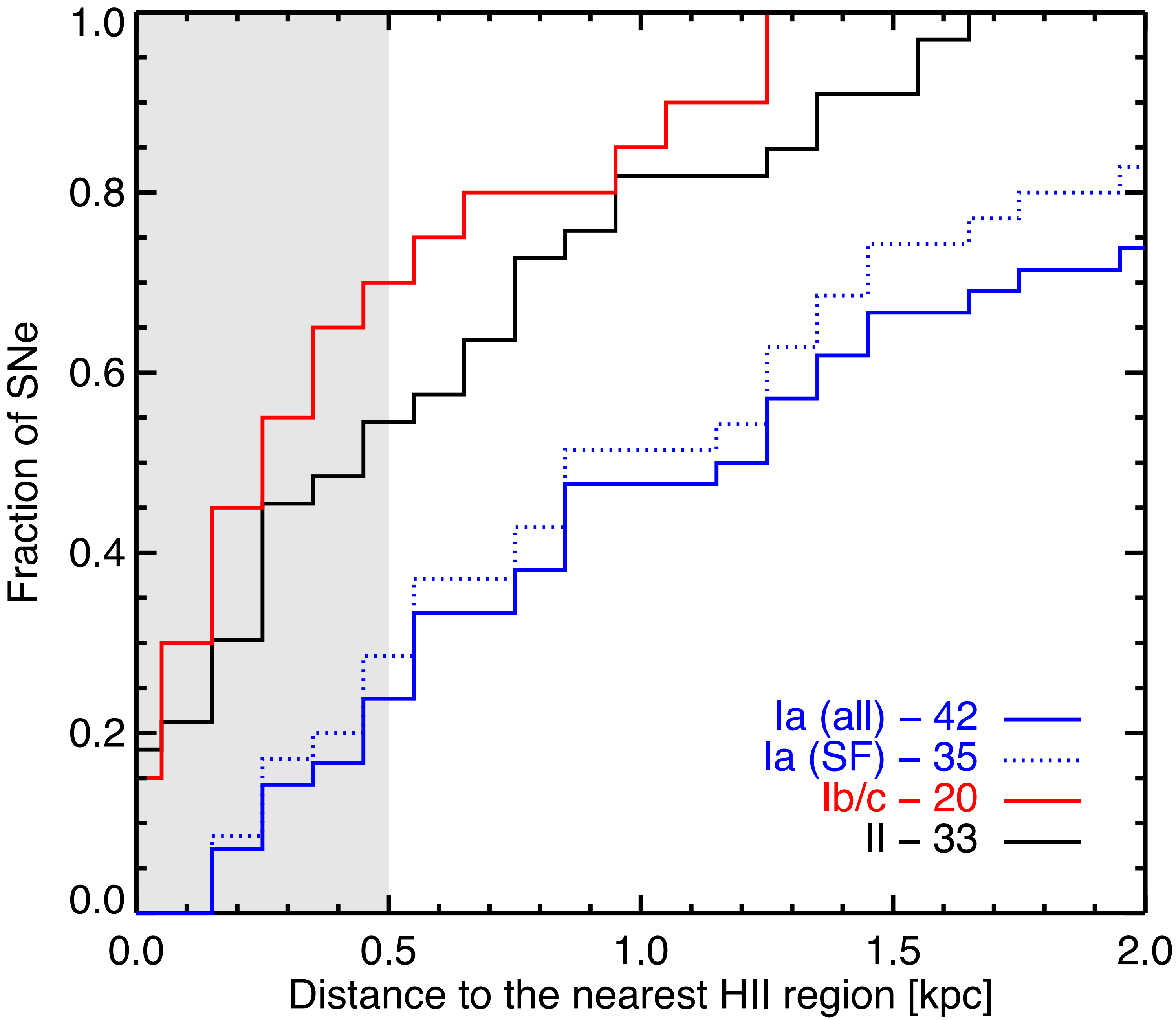


HII clupms selected from Hα maps using HIIexplorer

Sanchez+12

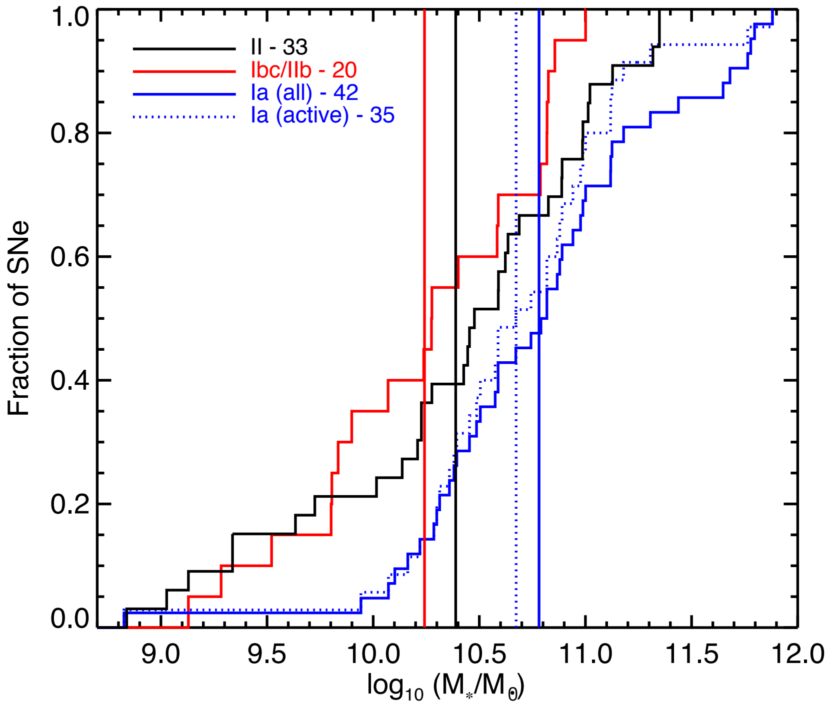
measure distances from the SN explosion site to the nearest HII clump

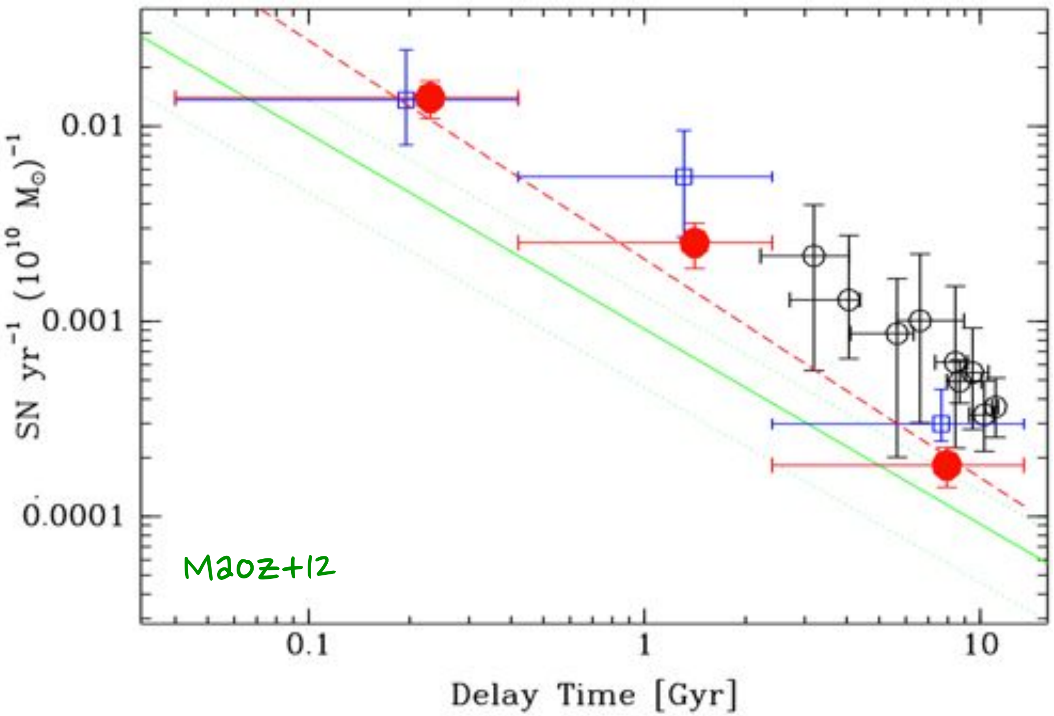
local host galaxy properties - star forming regions



II	0.647 (0.090)
Ibc/IIb	0.495 (0.095)
Ia-SF	1.376 (0.198)
Ia-all	2.376 (0.480)

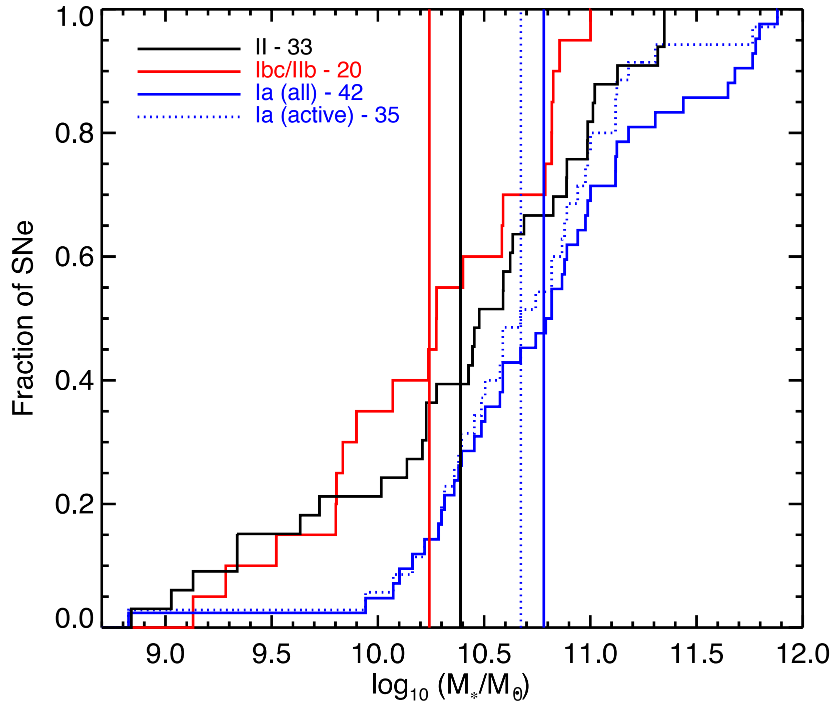
SN Ia rates

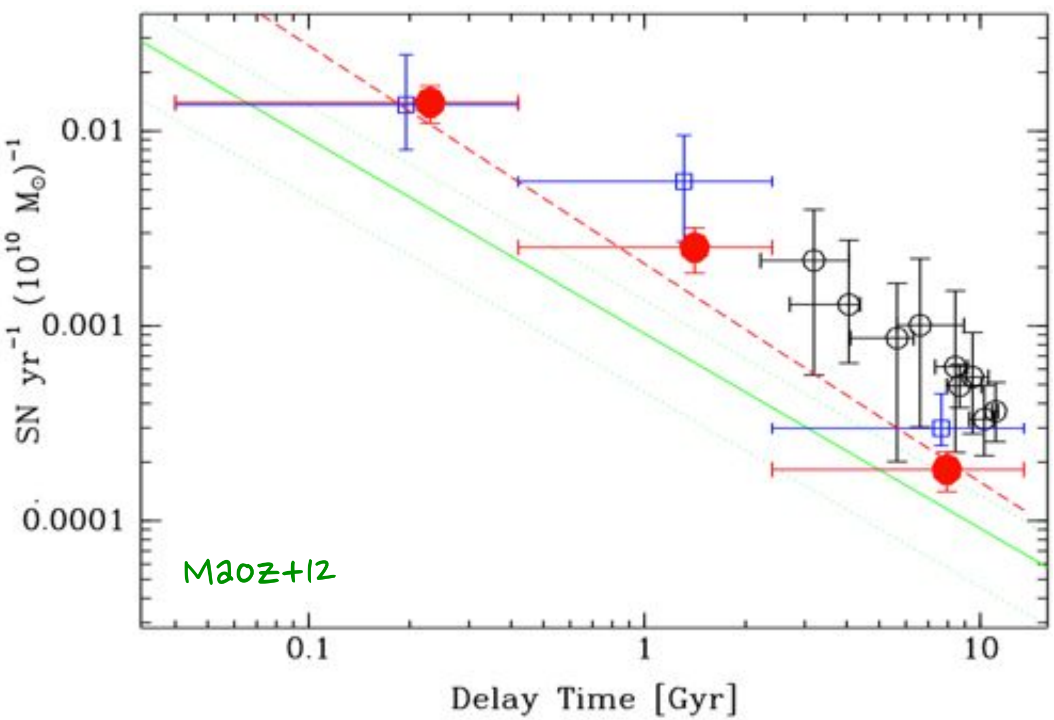




- SNIa hosts are more massive than ccSN hosts
- Explanation: different DTD
  - ccSNe rate proportional to SFR
  - SNeIa have a DTD~t^{-1} from 0.1 to 11 Gyr
- SFH in three bins (0-0.42 Gyr, 0.42-2.4 Gyr, 2.4-11 Gyr)

SN Ia rates





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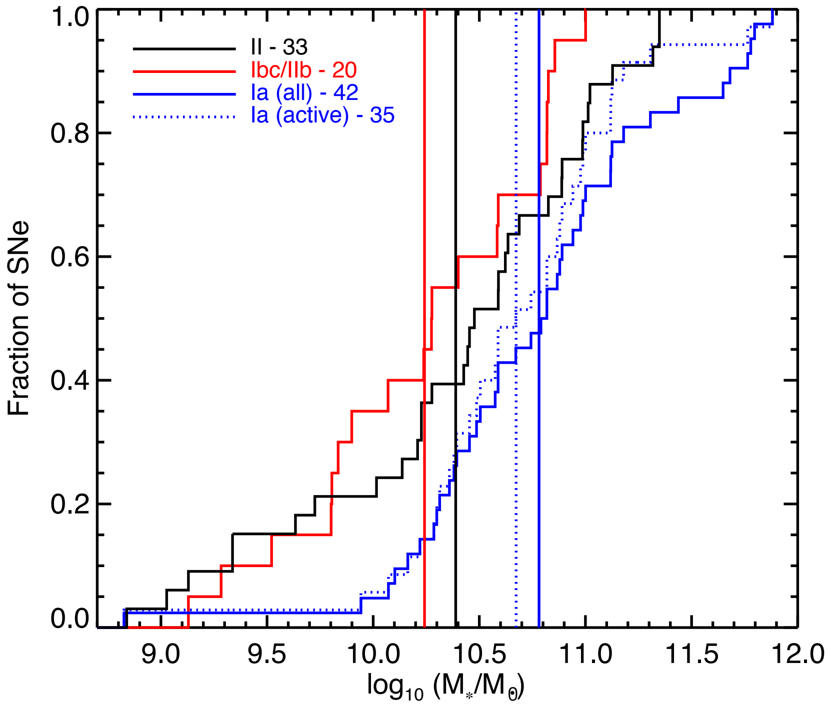
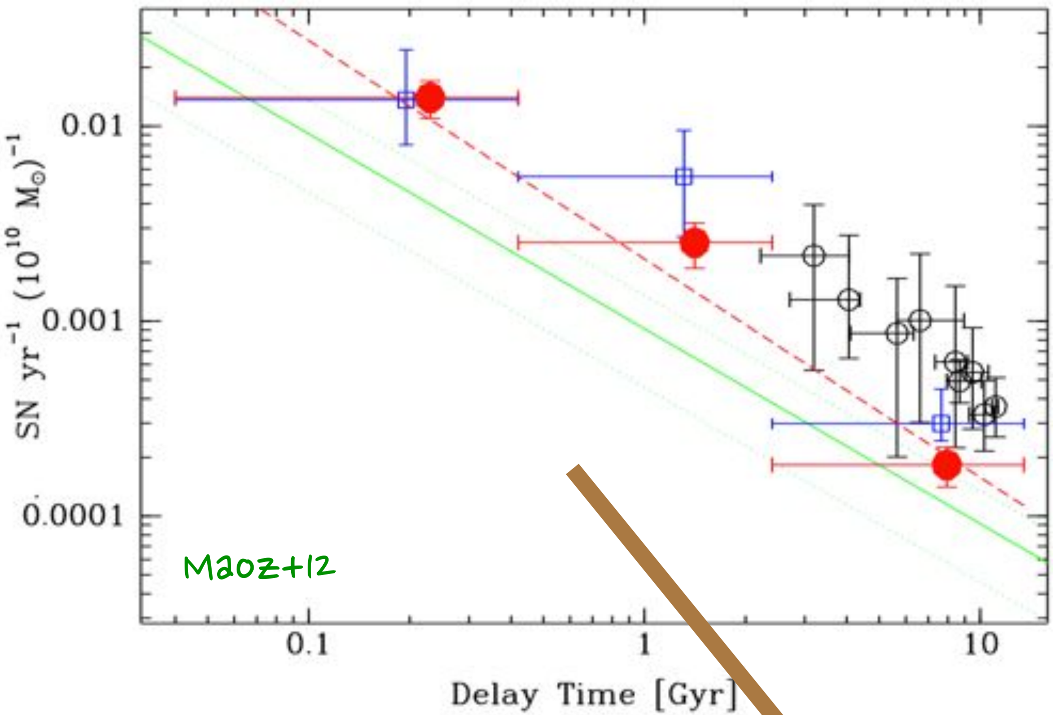
ccSN hosts:	0.10	3.4	96.52	(%)
SNIa hosts:	0.04	2.0	97.95	(%)

SN Ia rates





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2x more SNIa produced in SNIa hosts

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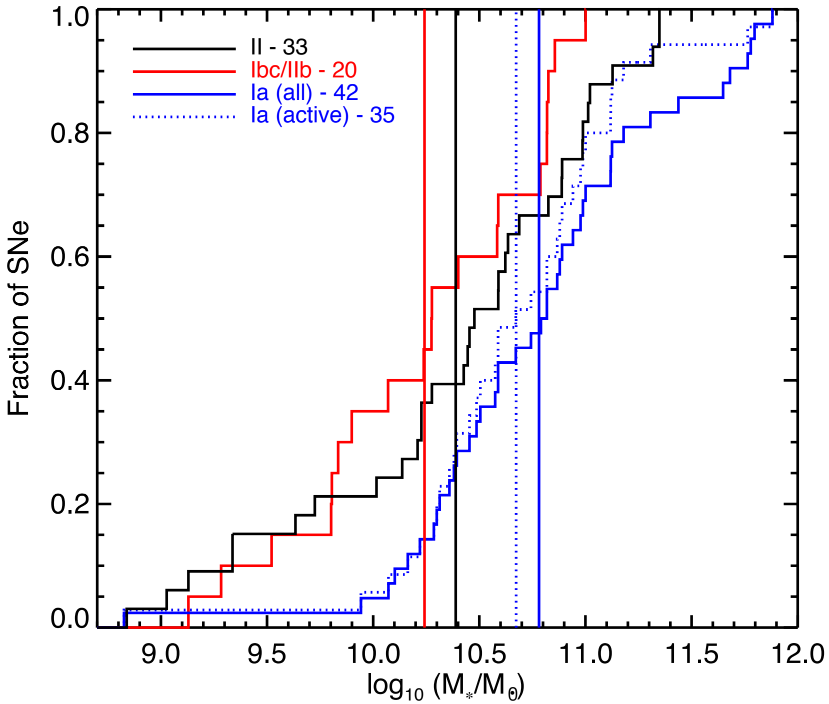
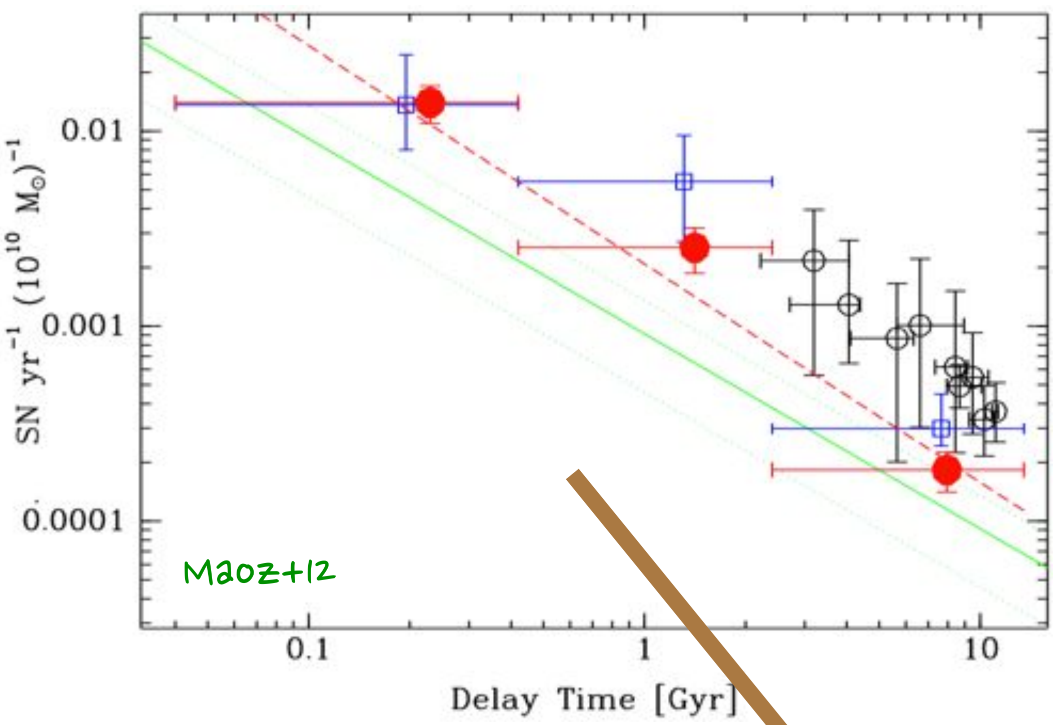
SN Ia rates

2-5 20-30 65-75 (%)





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SN Ia rates

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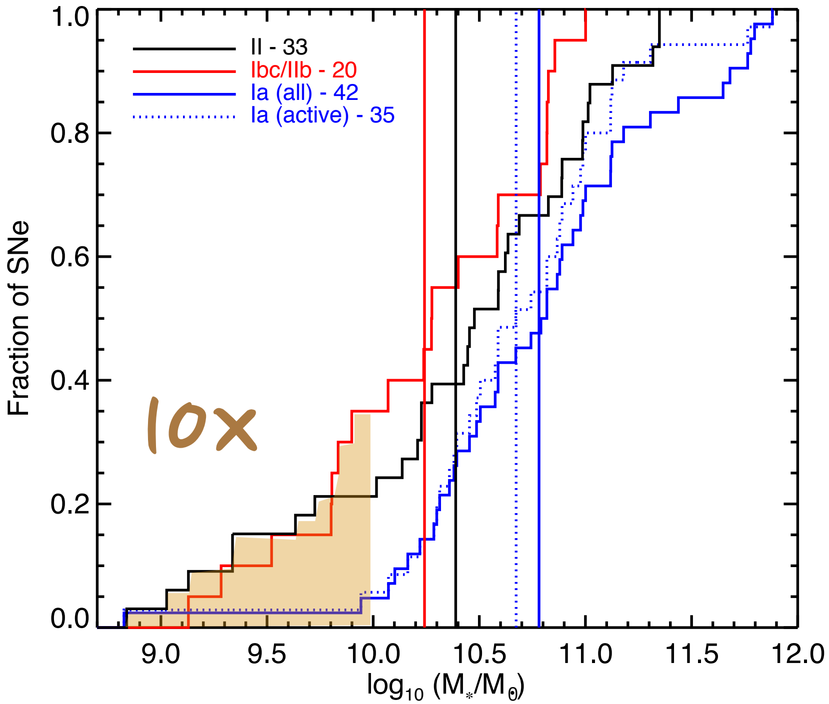

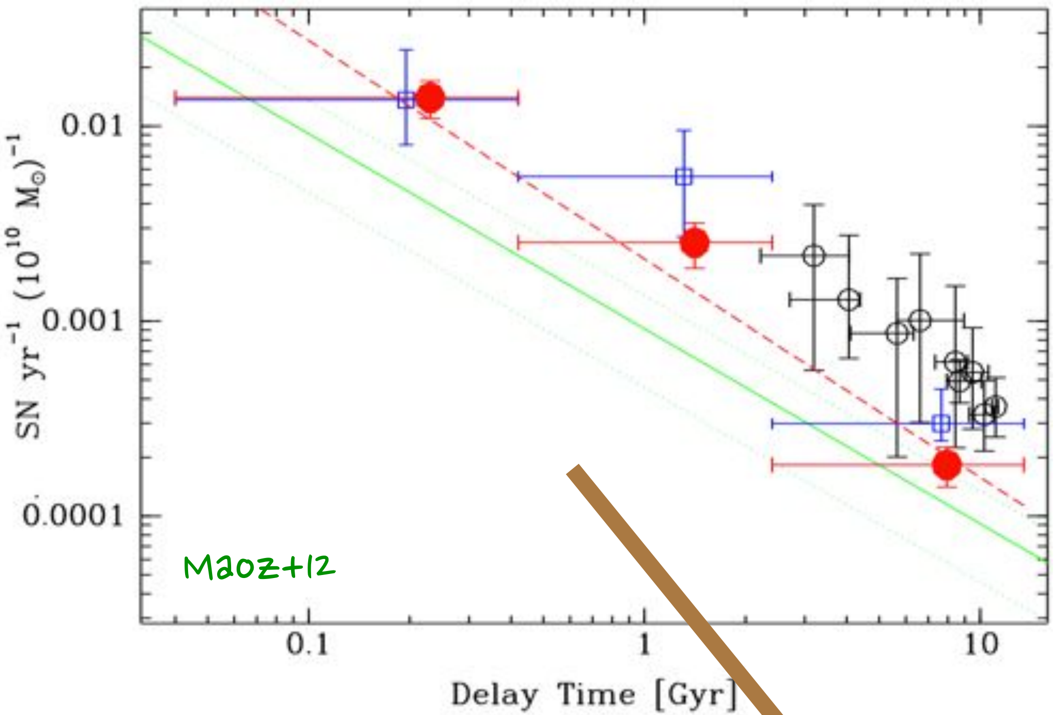

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cc SN rates

- ccSN rate is proportional to the SFR

SN Ia hosts	1.51 Msun yr^{-1}
low-mass end cc SN hosts	0.51 Msun yr-1

cc SN rates

- ccSN rate is proportional to the SFR

SN Ia hosts	1.51 Msun yr^{-1}	→	3 times more ccSN produced in SNIa hosts
low-mass end cc SN hosts	0.51 Msun yr-1		

cc SN rates

- ccSN rate is proportional to the SFR

SN Ia hosts 1.51 Msun yr^{-1}

low-mass end cc SN hosts 0.51 Msun yr-1

→ 3 times more ccSN produced in SNIa hosts

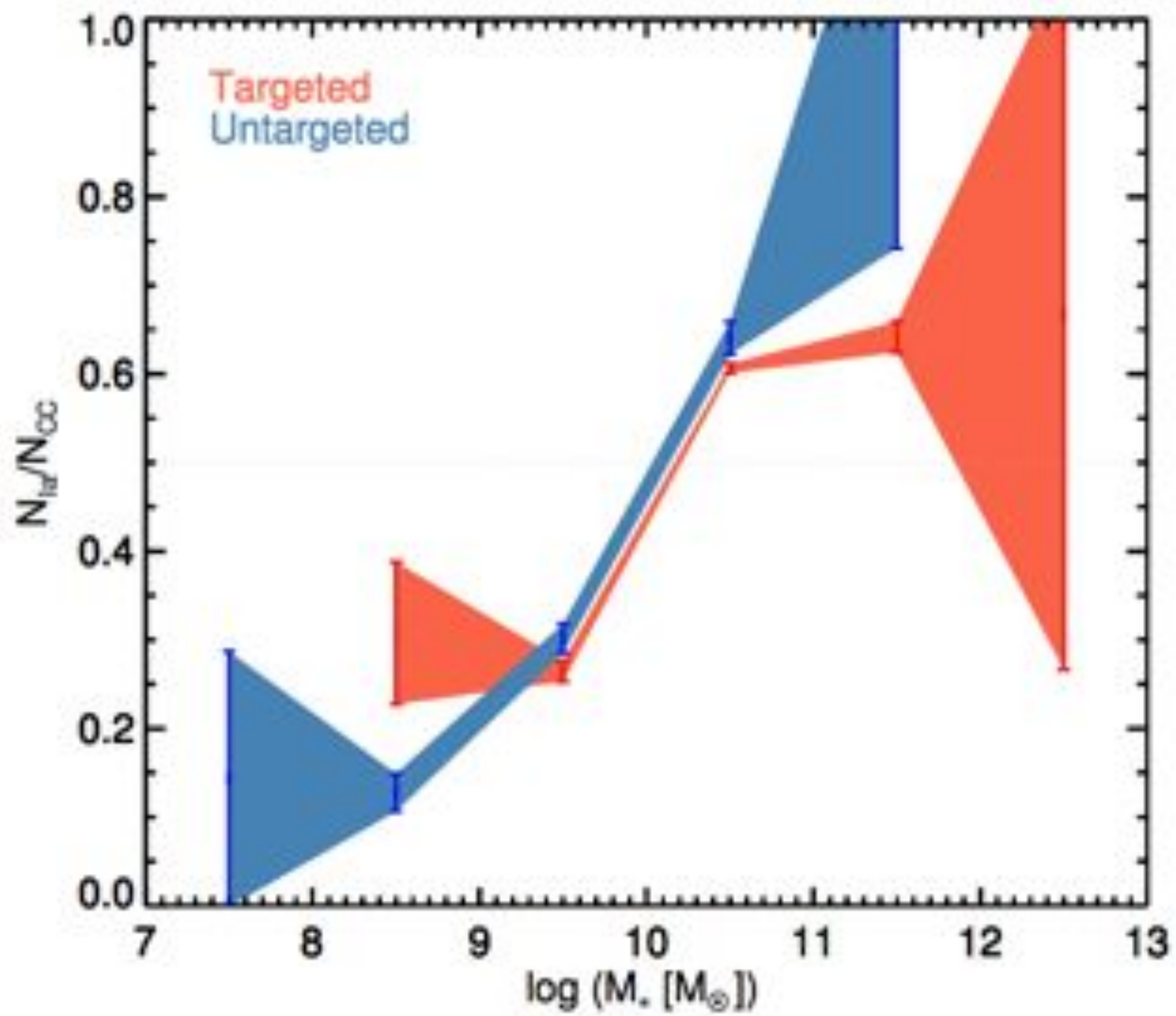
CALIFA sample

+

Sample compiled from the literature

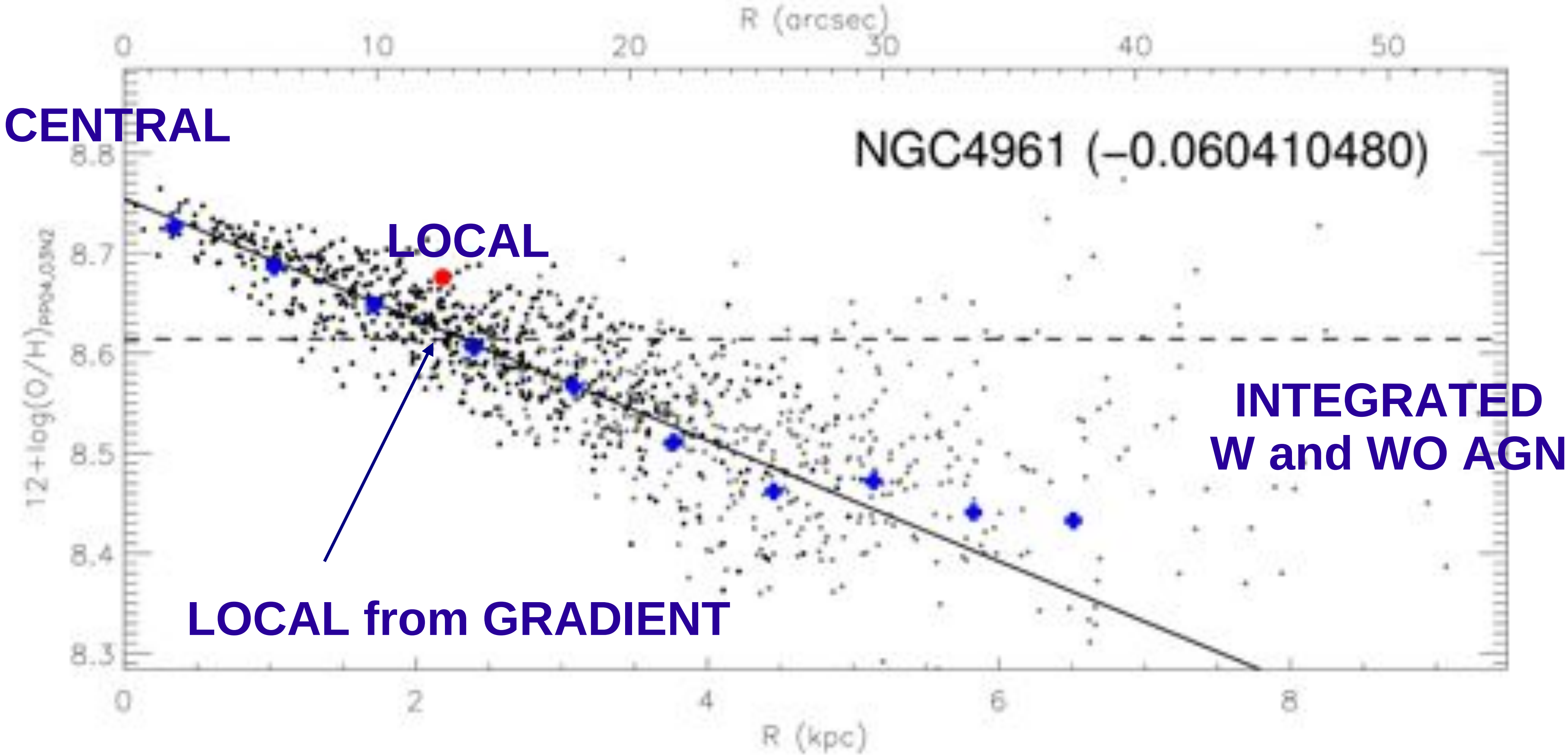
Pan+14 Stoll+13

Kelly+12 Neill+09

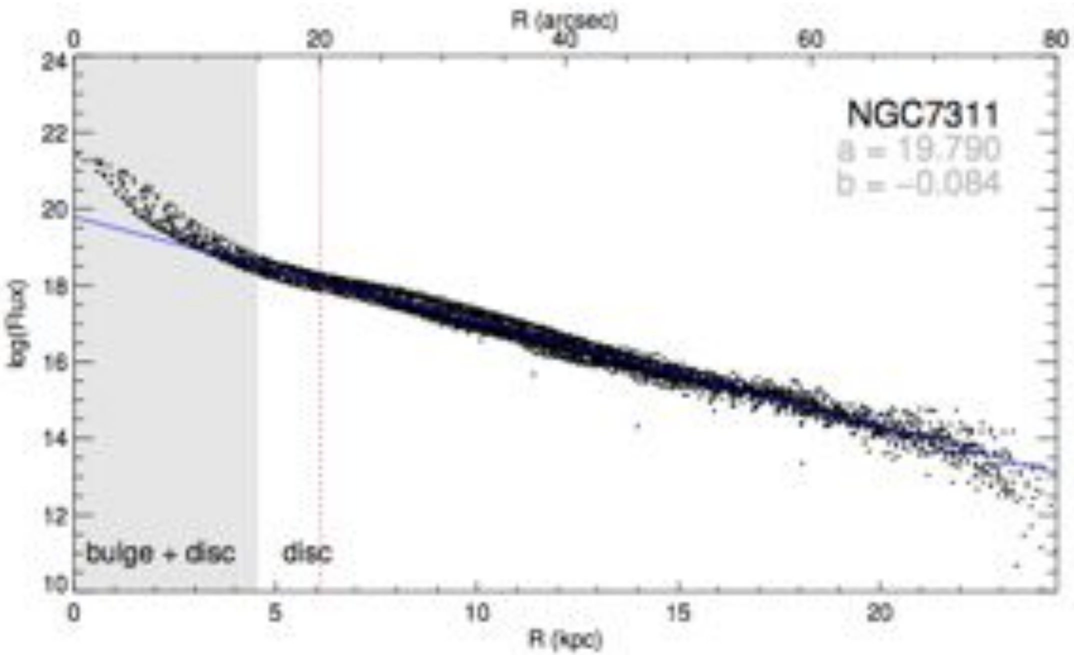


PAPER II !!!

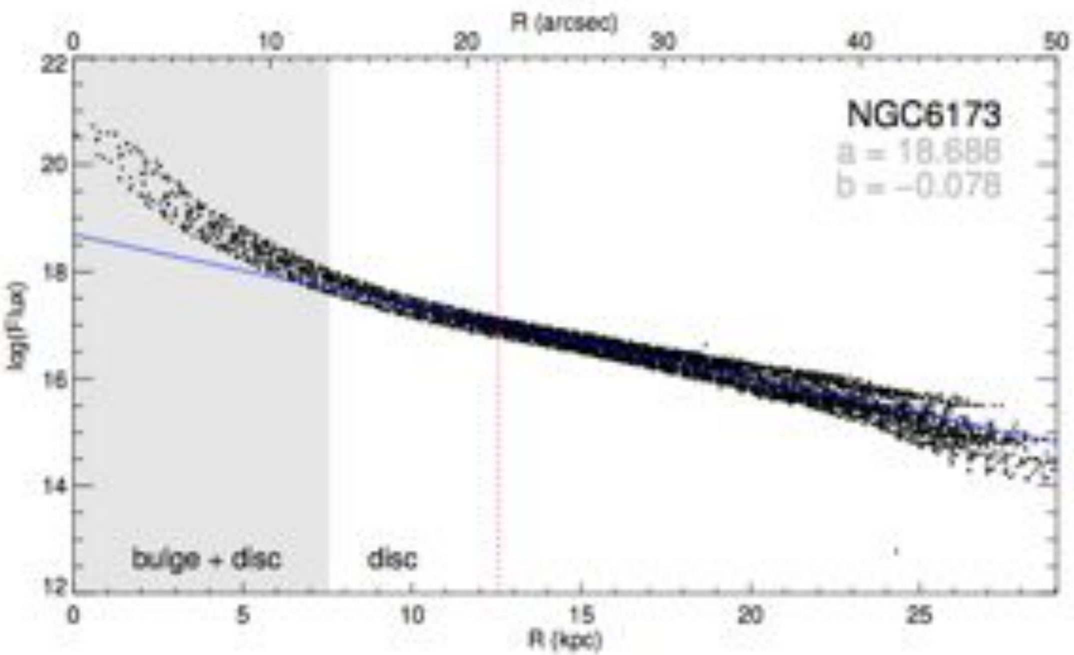
local host galaxy properties - oxygen abundance



disk effective radius (r_e)

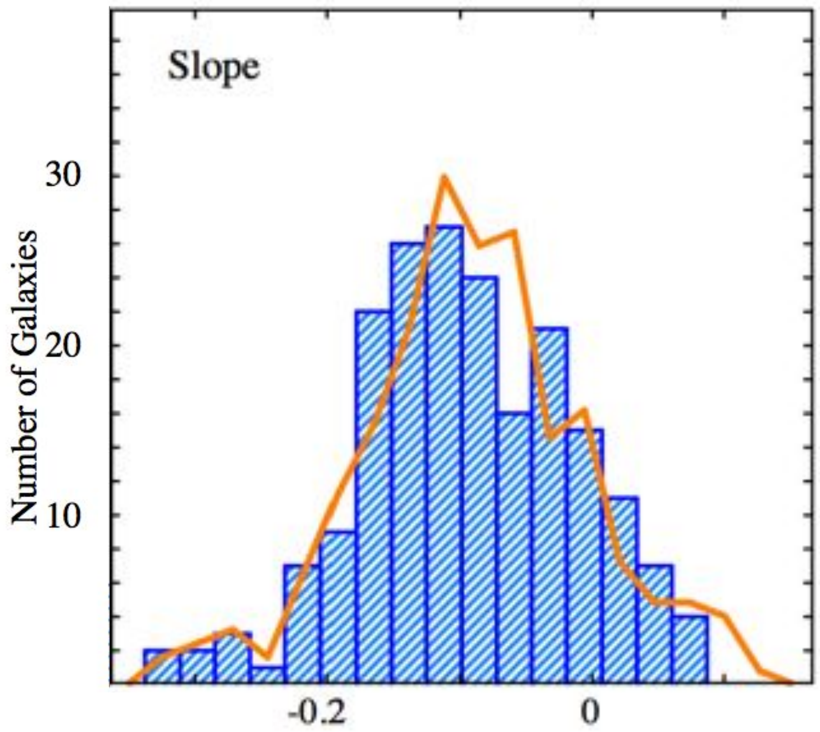


determination of the disk effective radius by fitting the light profile contribution from the disk

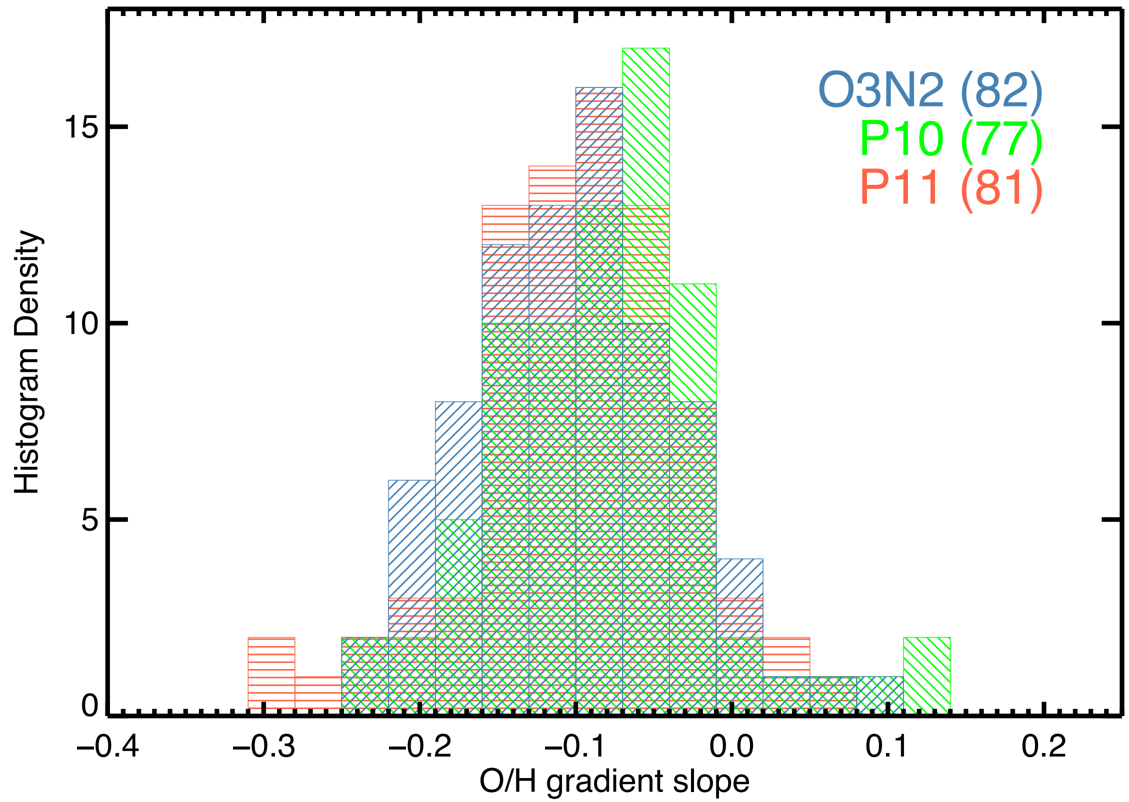


decoupling bulge and disk using the projection of the r-band brightness

local host galaxy properties - metallicity gradients



Sanchez+13

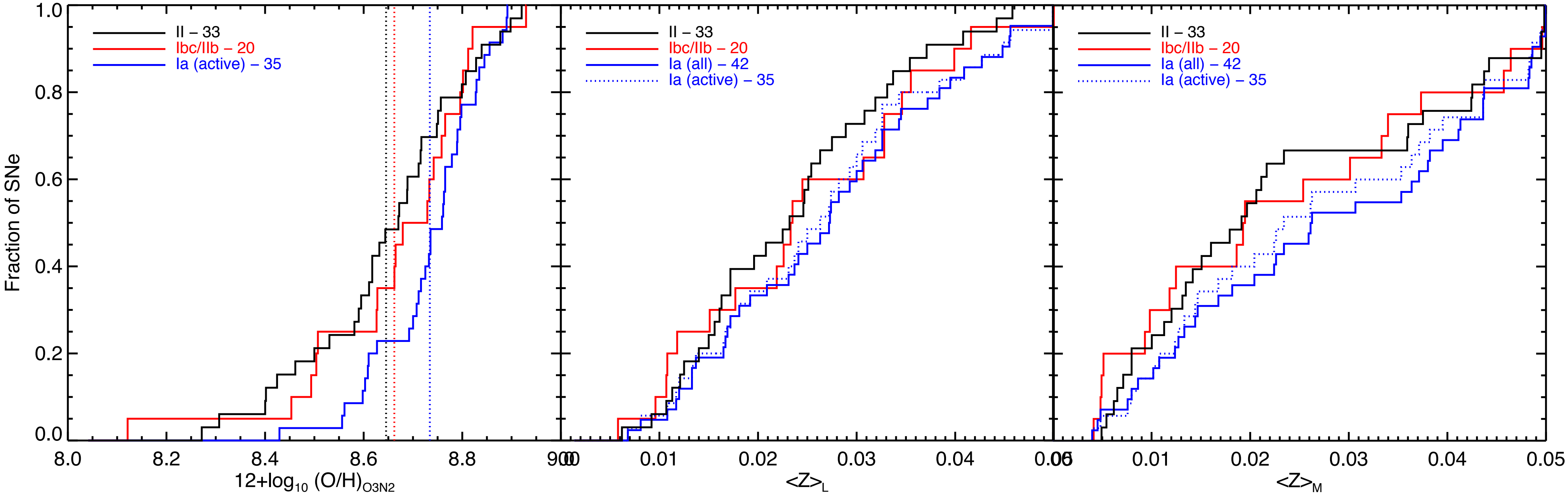


show a characteristic gradient (~ −0.1 dex/Re)

no dependence on O/H estimator or SN type

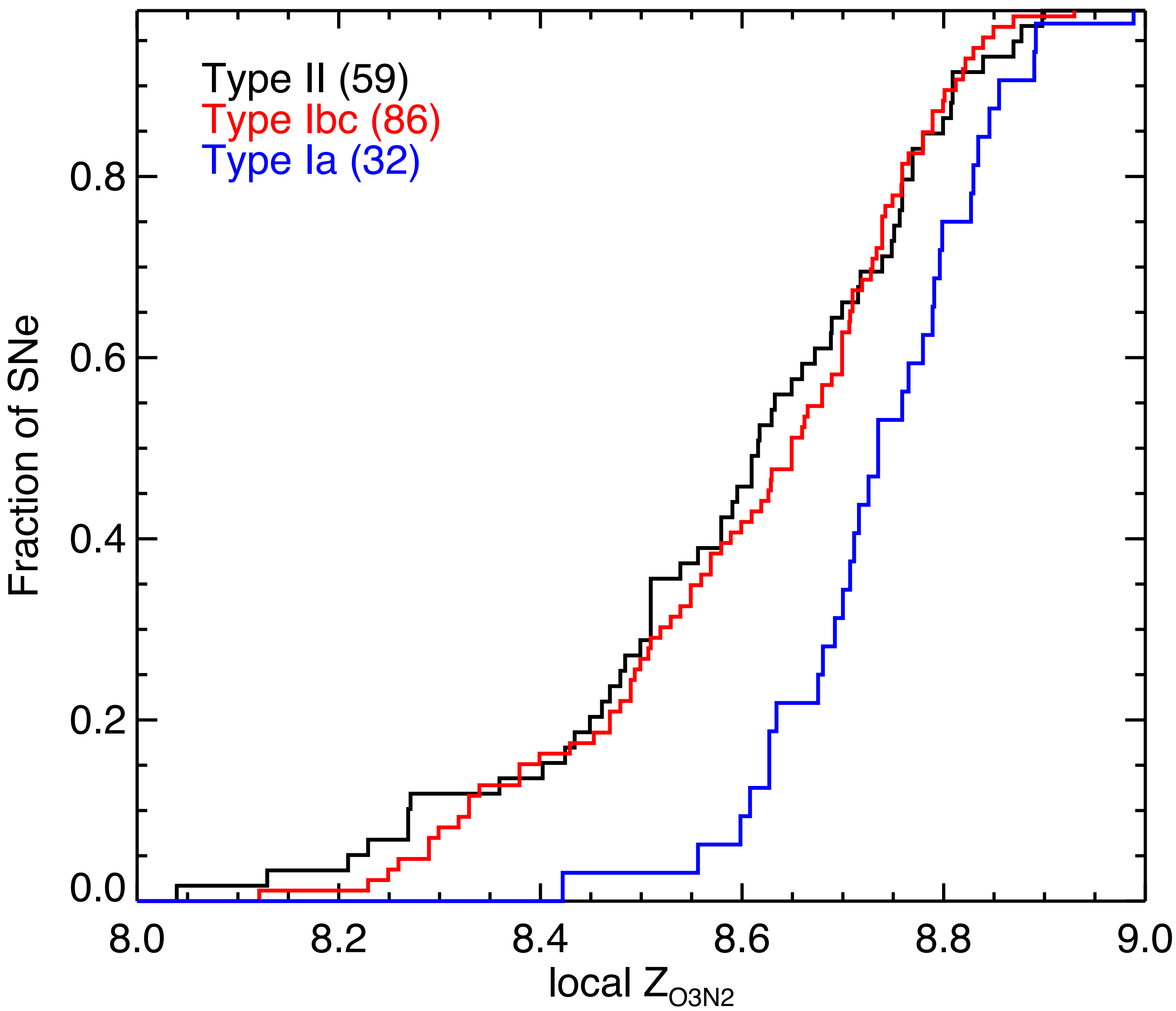
local host galaxy properties - local metallicity

- oxygen abundance from the emission lines (with several indicators)
- stellar metallicity from the fit to the continuum fit (Z_L, Z_M)



II	8.645 (0.029)	II	0.023 (0.002)	II	0.024 (0.003)
Ibc/IIb	8.662 (0.040)	Ibc/IIb	0.025 (0.003)	Ibc/IIb	0.024 (0.004)
Ia -SF	8.734 (0.018)	Ia -SF	0.026 (0.002)	Ia -SF	0.027 (0.003)
		Ia-all	0.027 (0.002)	Ia-all	0.028 (0.002)

local host galaxy properties - local metallicity

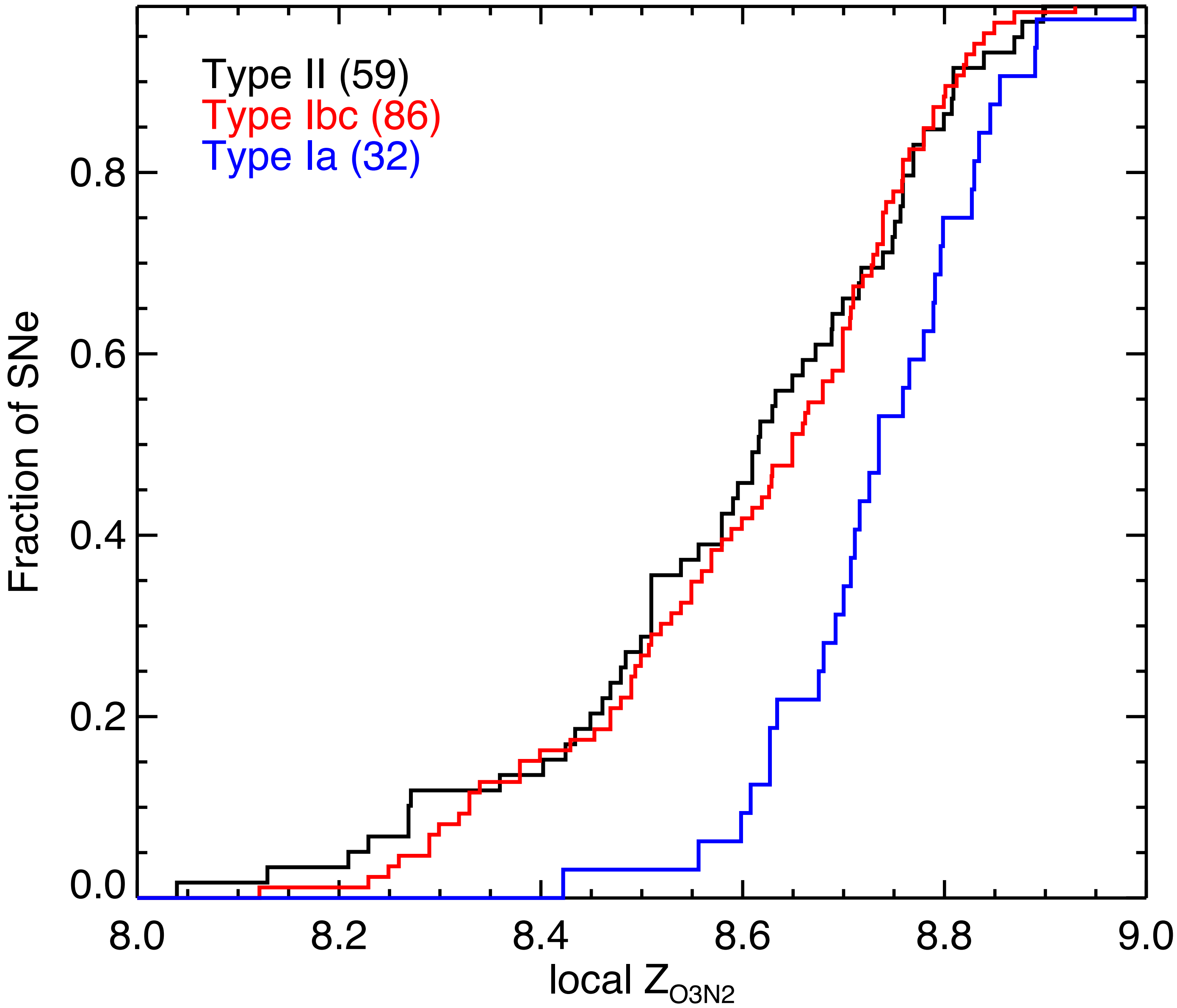


CALIFA sample

+

Sample compiled from the literature

local host galaxy properties - local metallicity



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+

Sample compiled from the literature

Kuncarayakti+13ab

Anderson+10

Anderson+11

Modjaz+11

Leloudas+11

Sanders+12

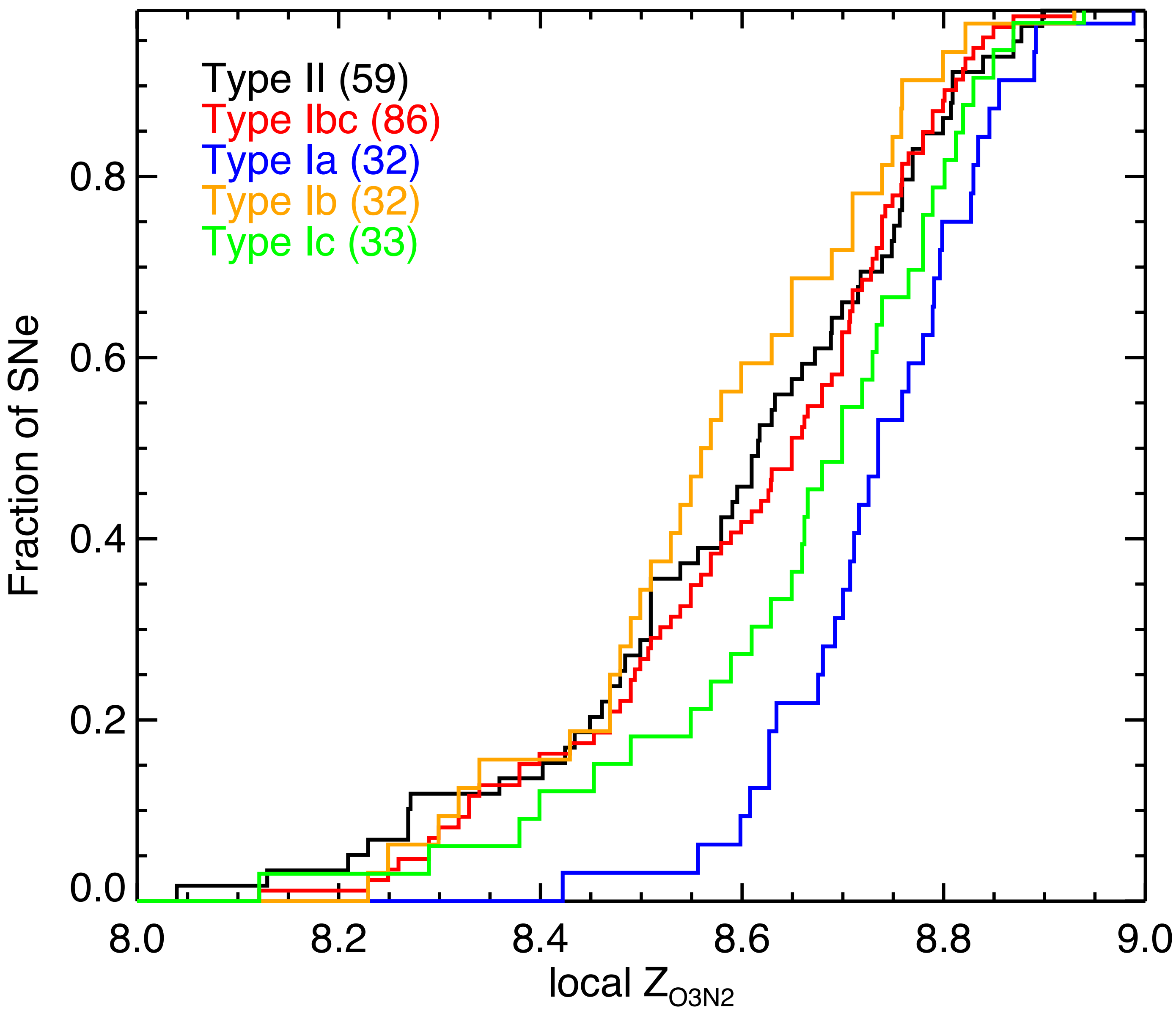
Young+10

Habergham+12

Tomasella+12

Prieto+12

local host galaxy properties - local metallicity



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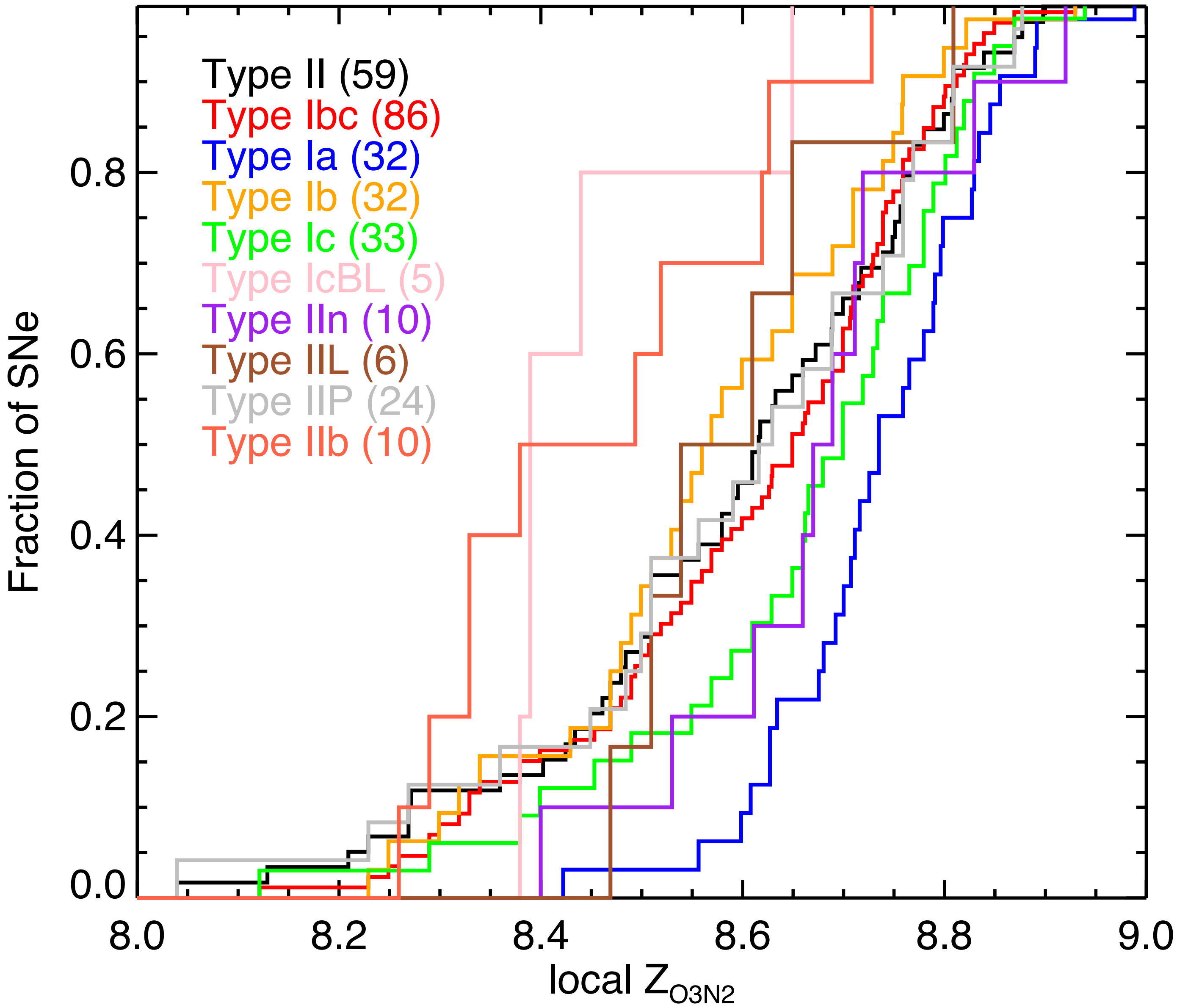

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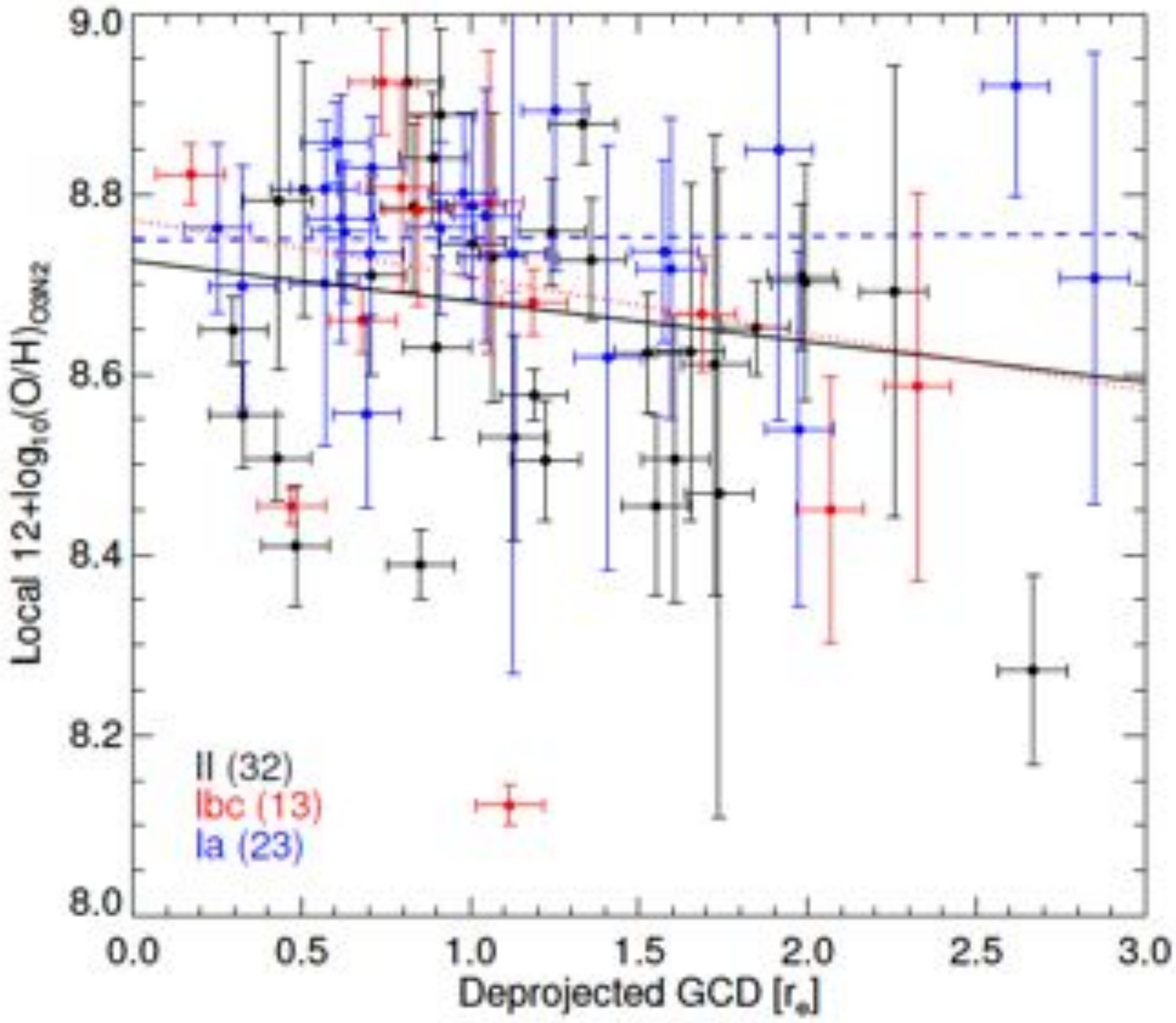
Prieto+12

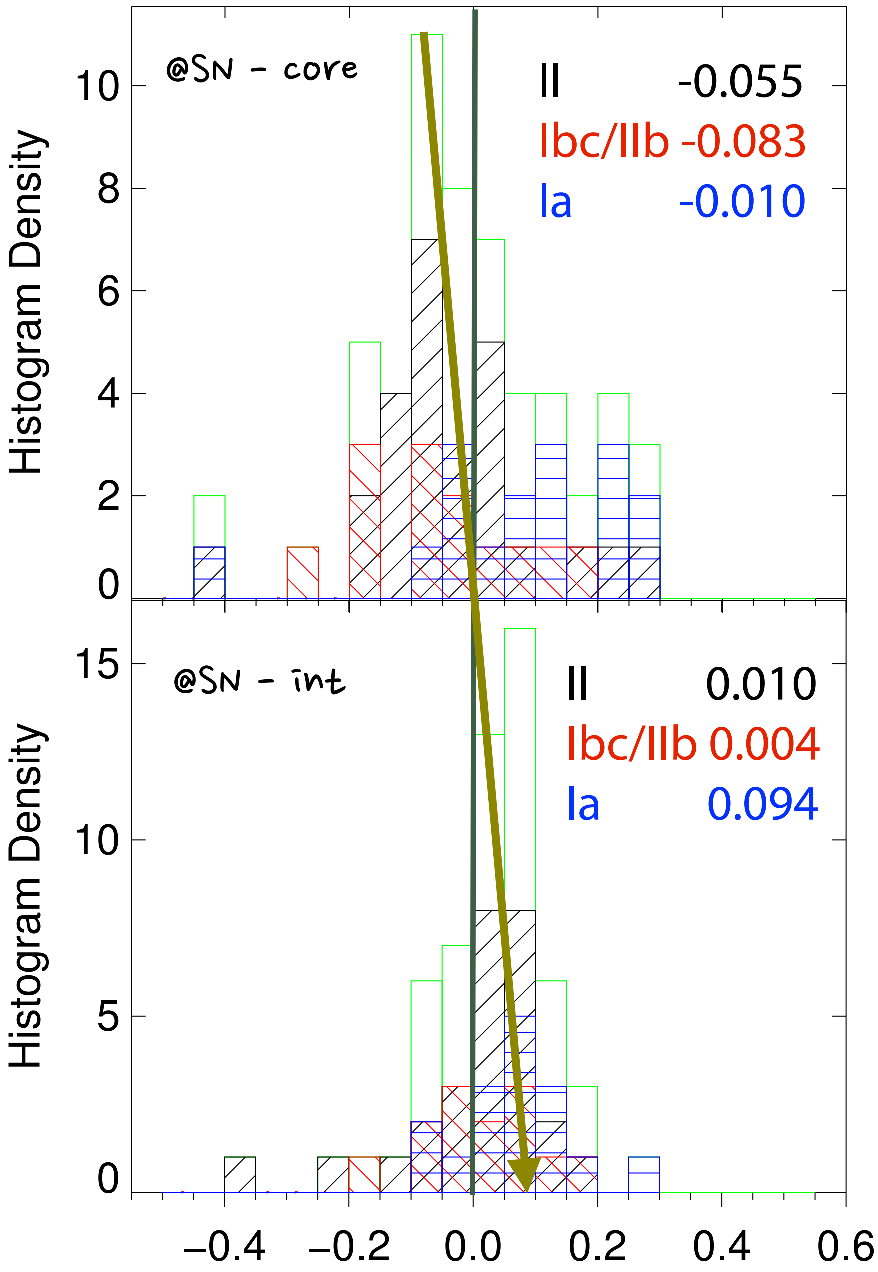
local host galaxy properties - metallicity gradients

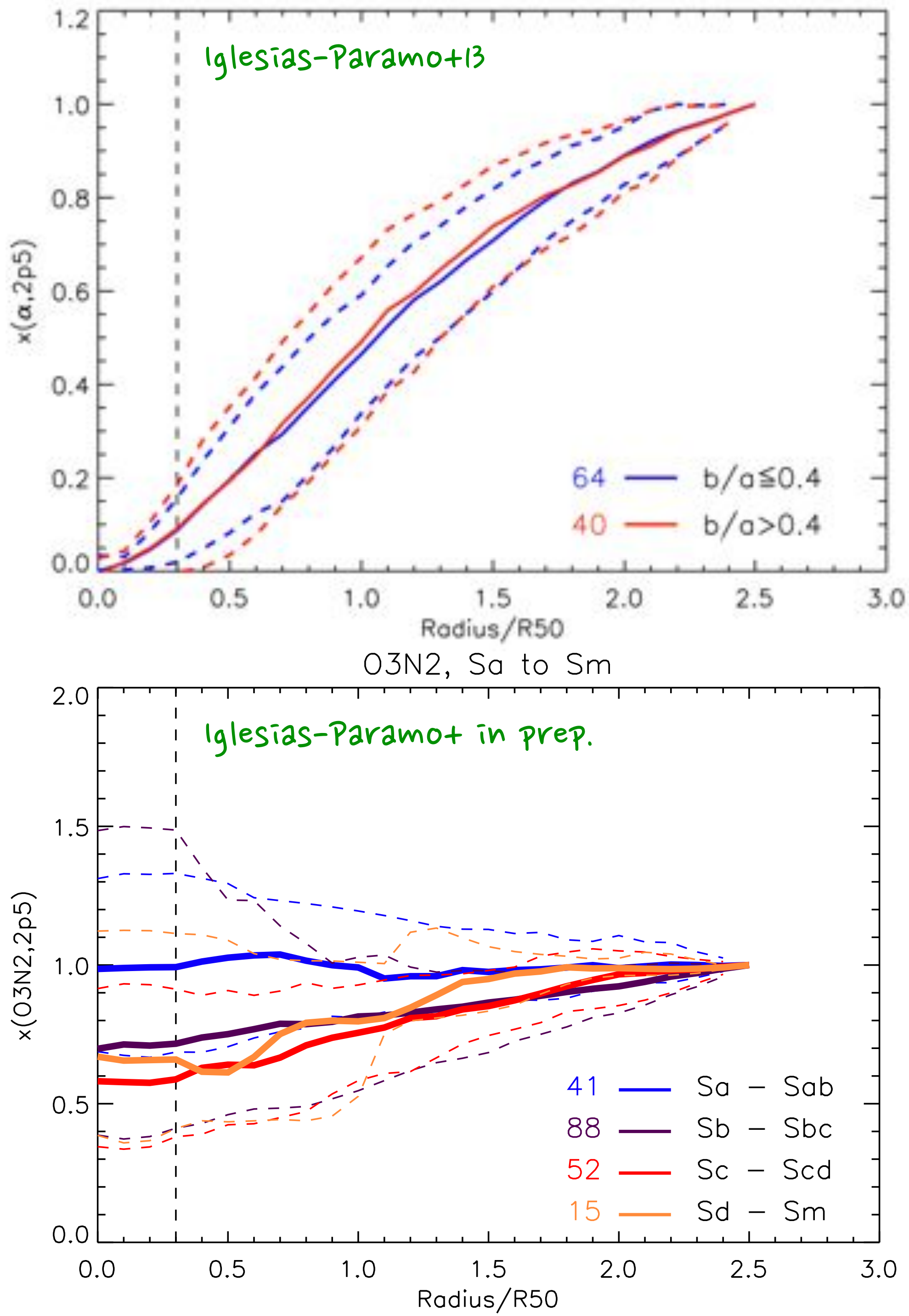


cc SNe local metalicity have lower values in the outskirts

SNe Ia do not show a decrease in metallicity at larger distances

aperture effects

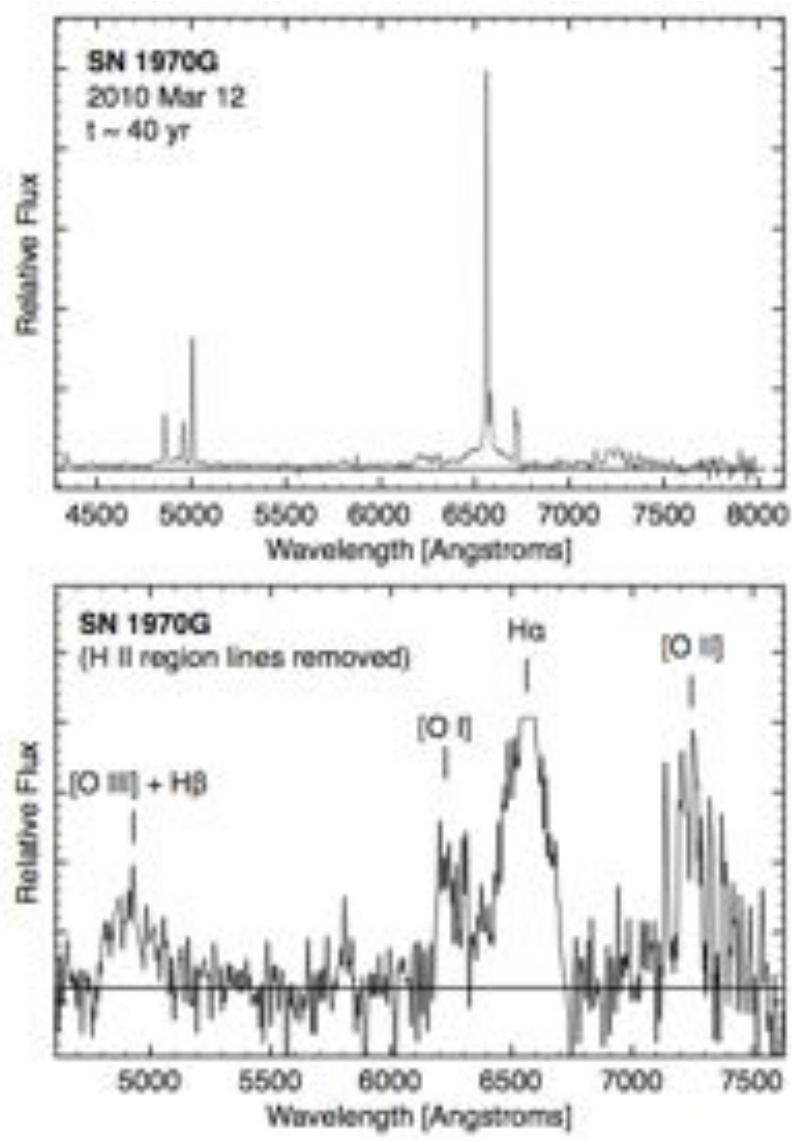




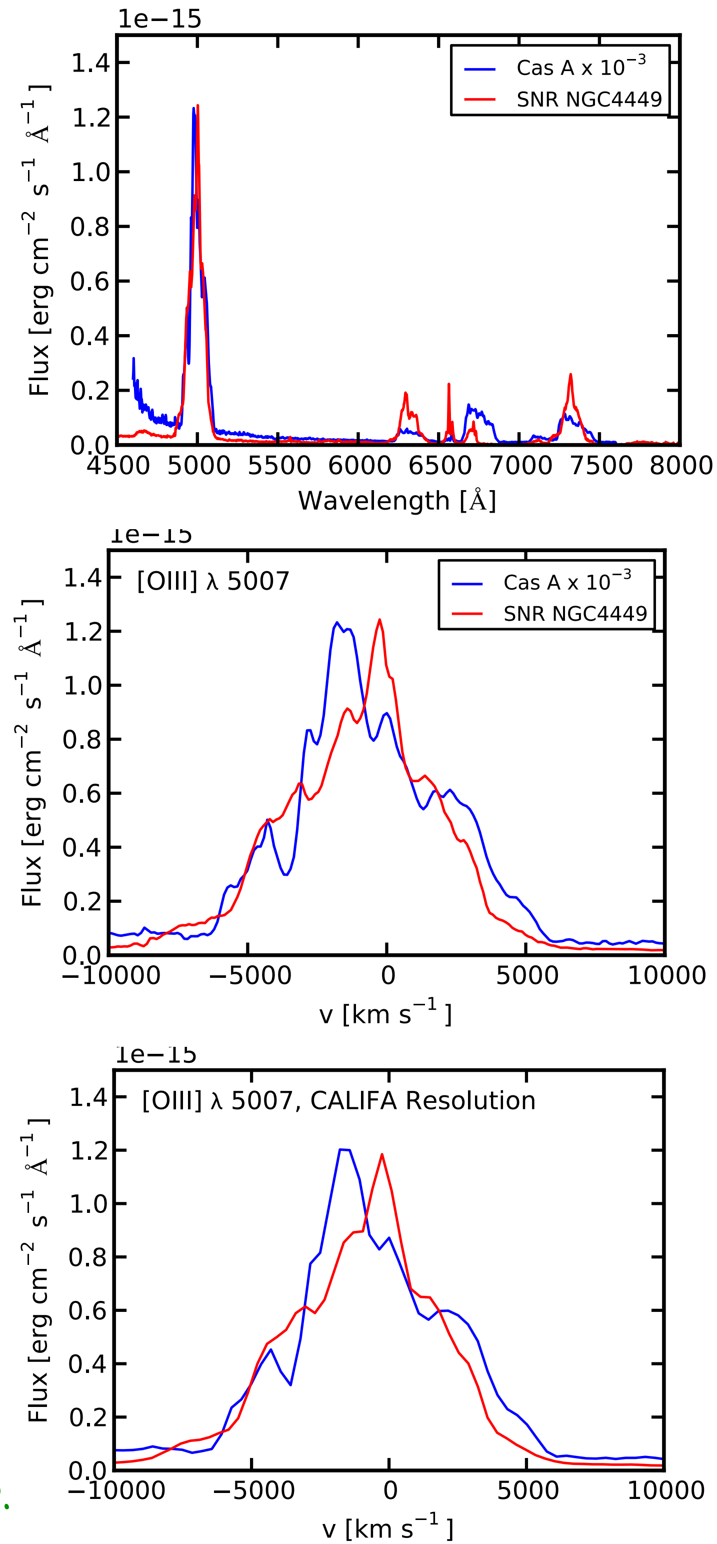
SN remnants in CALIFA

col.: C. Badenes, U. Pittsbourgh

"young" SNR: broad emission



Milisavljevic+12



Badenes+ in prep.

SN remnants in CALIFA

"old" SNR: SII/Hα ratio > 0.4 Mathewson & Clarke (1973)

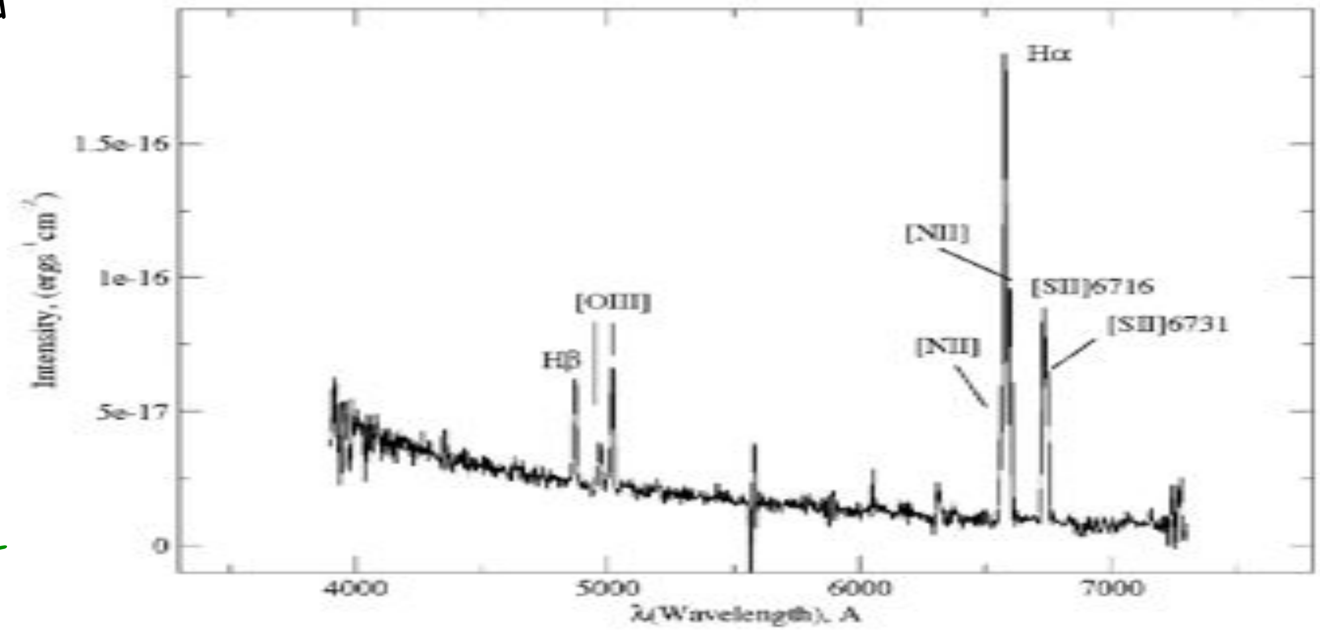
In a typical H II region sulfur is in the form of S^{++} due to strong photoionizing fluxes from central hot stars, making the ratio [S II]/Hα, typically, in the range ∼ 0.1 – 0.3.

Shock waves produced by SN explosions propagate through the surrounding medium.

The matter cools sufficiently behind these waves and variety of ionization states occur including S^{+}.

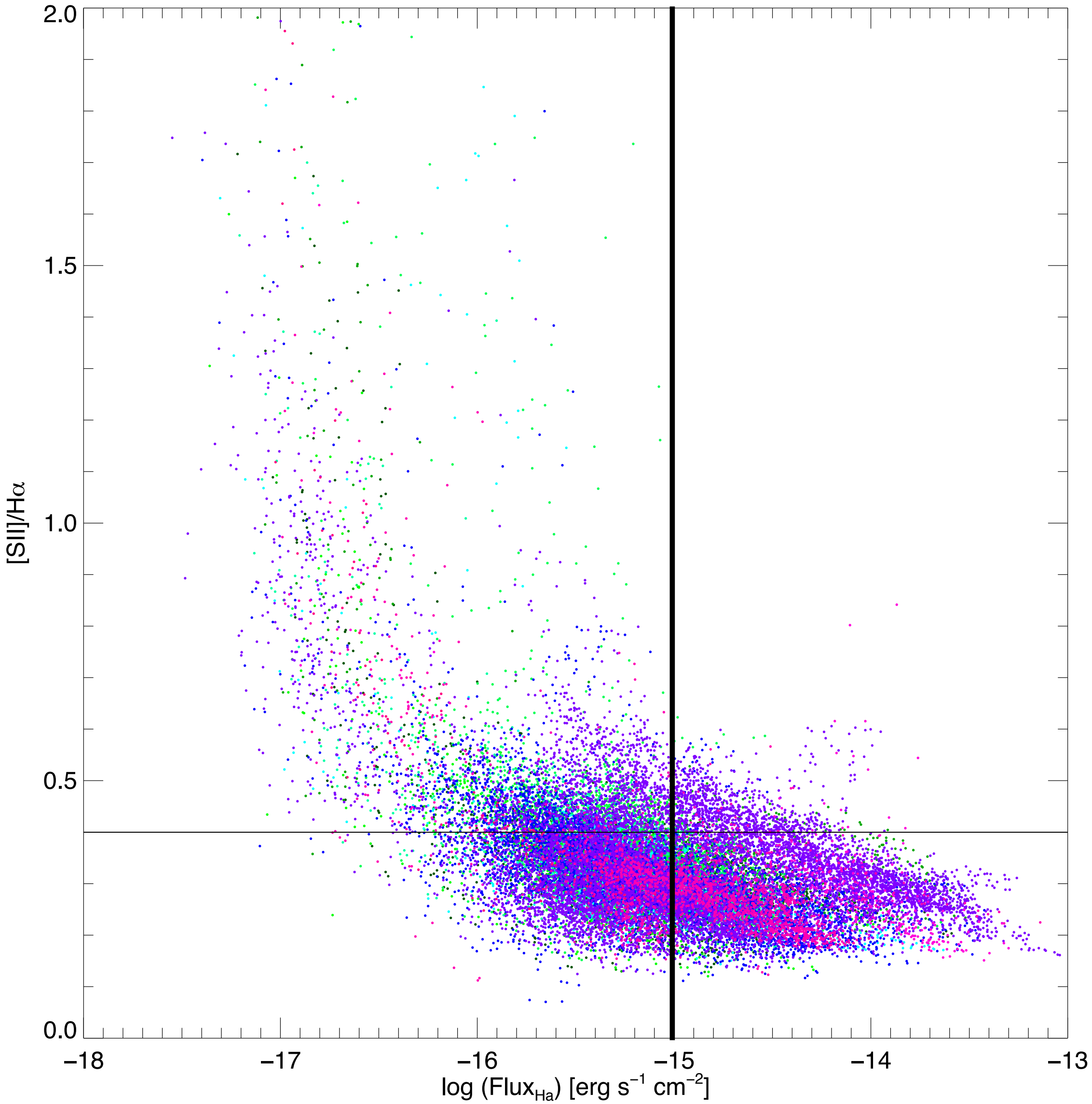
This might be the reason for the increased [SII]/Hα ratio observed in SNRs.

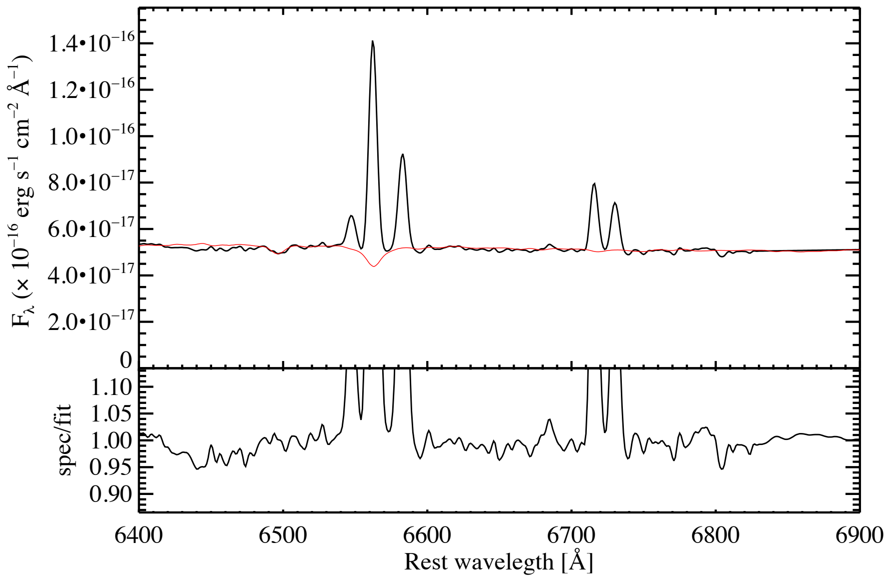
It follows that almost all discrete emission nebulae satisfying the above criterion are expected to be shock-heated



Sonbas+14

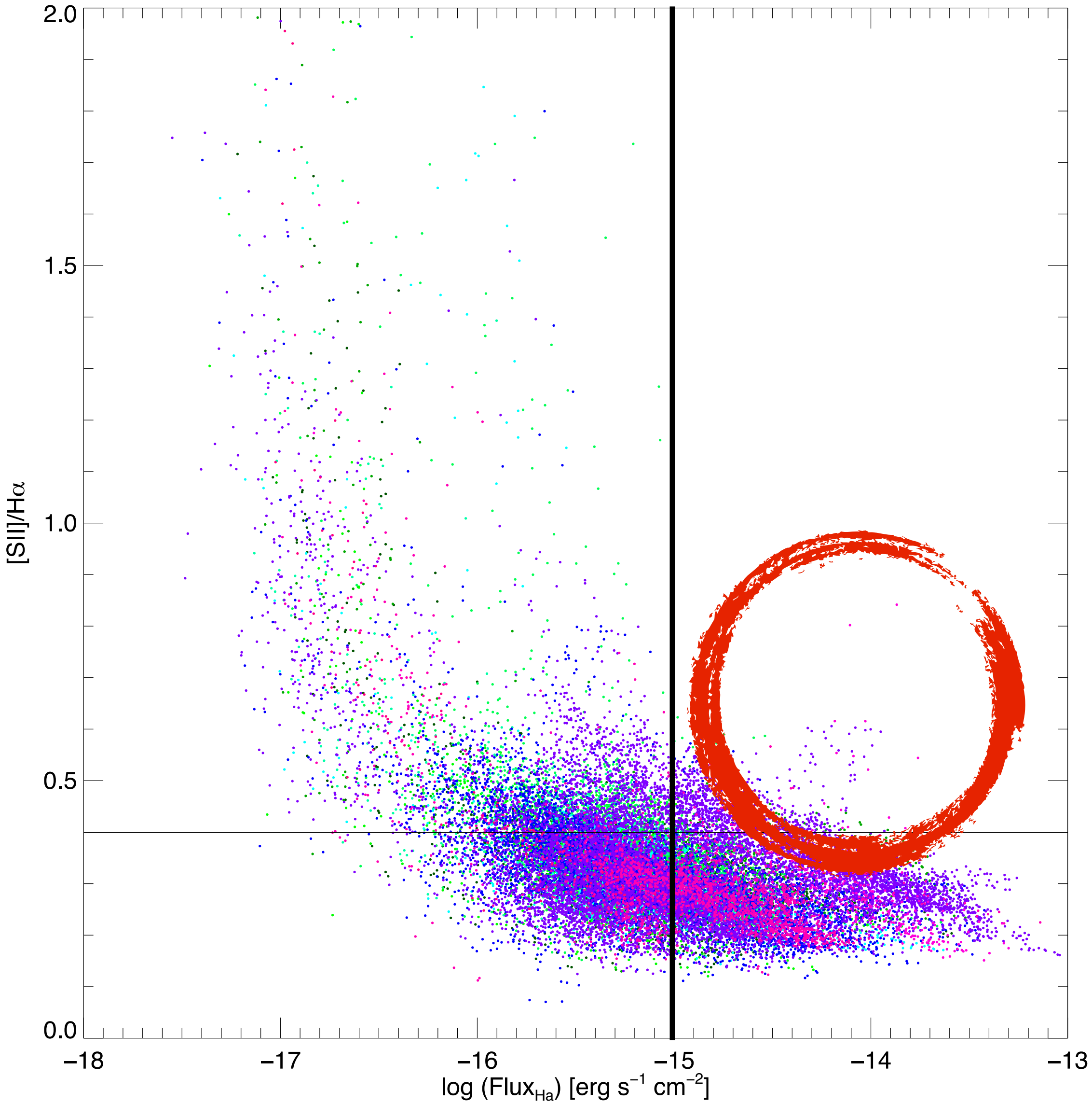
SN remnants in CALIFA

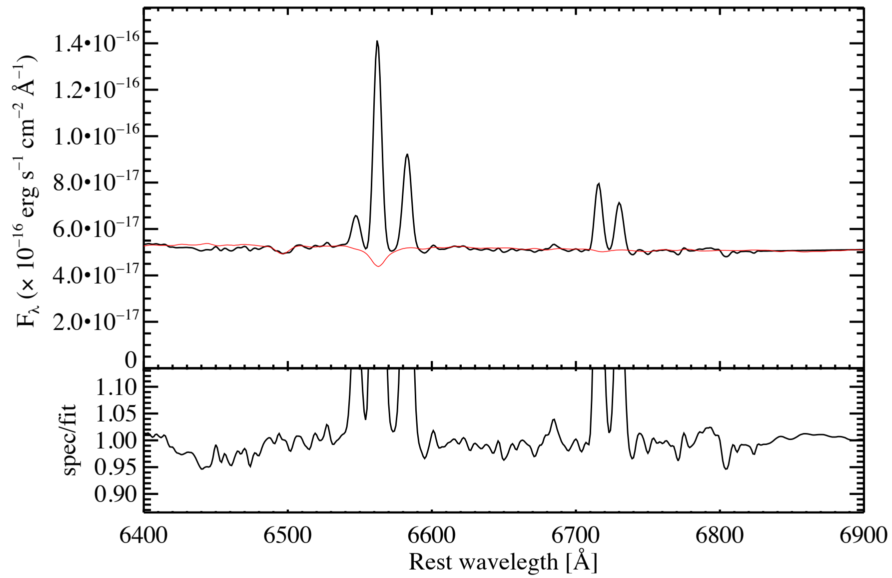




Galbany+ in prep.

SN remnants in CALIFA





Galbany+ in prep.

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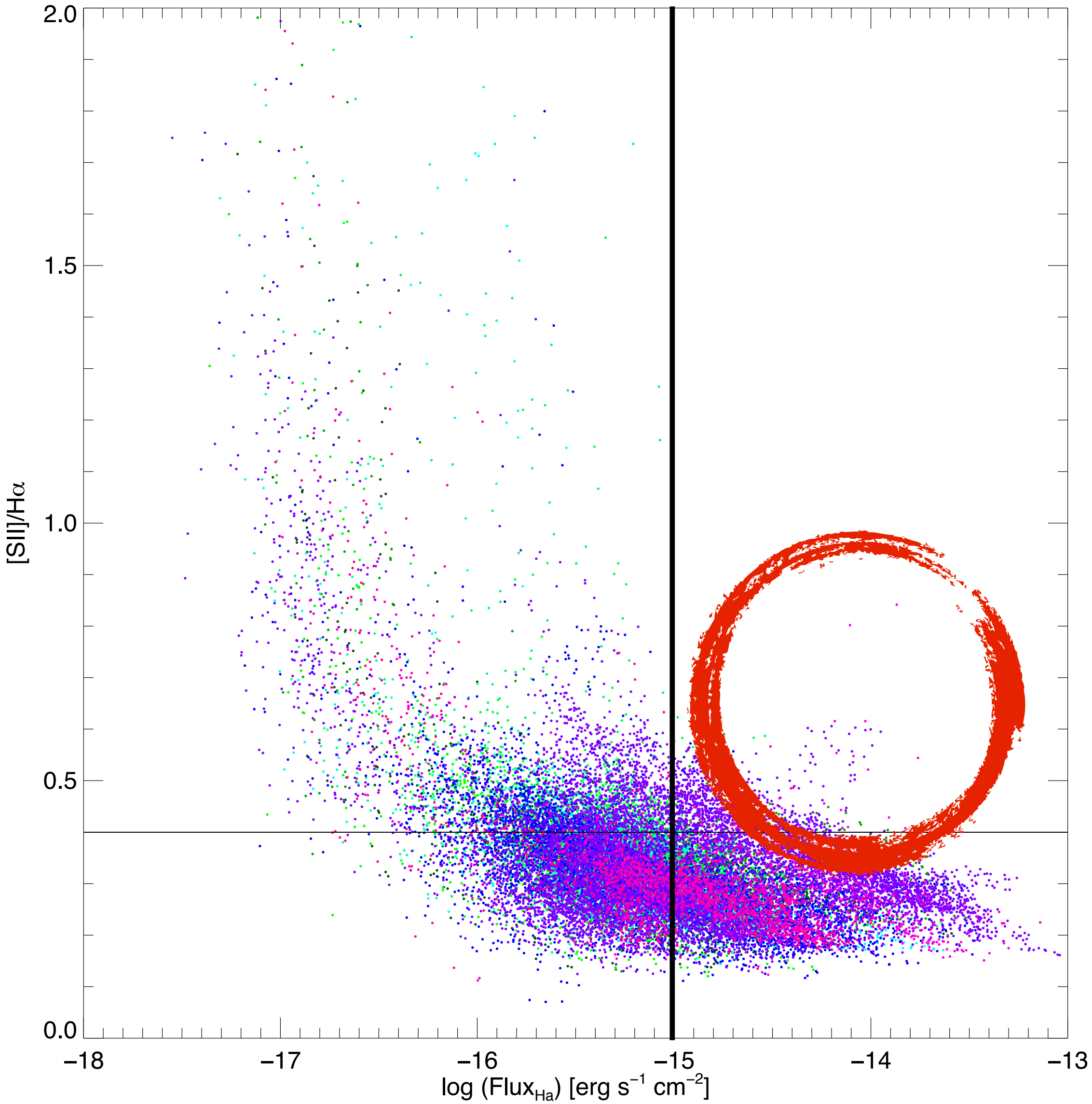
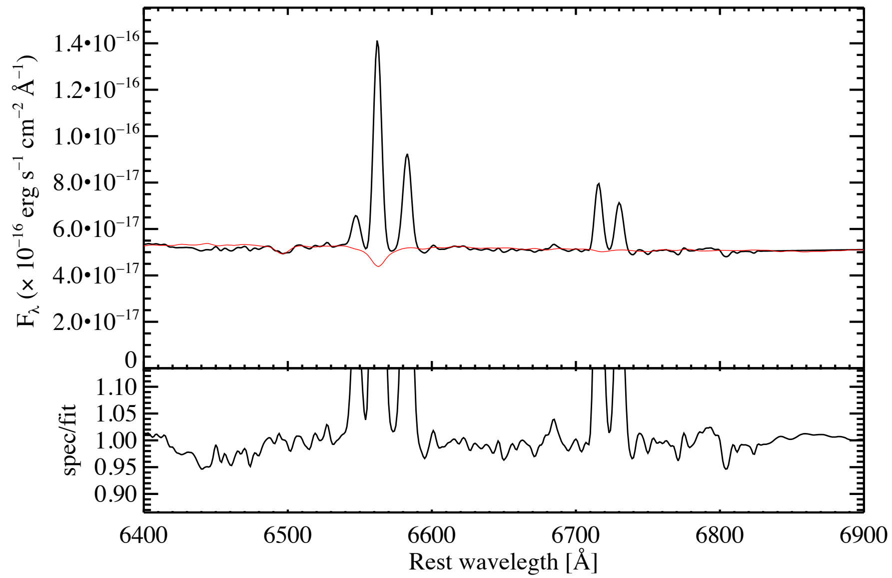
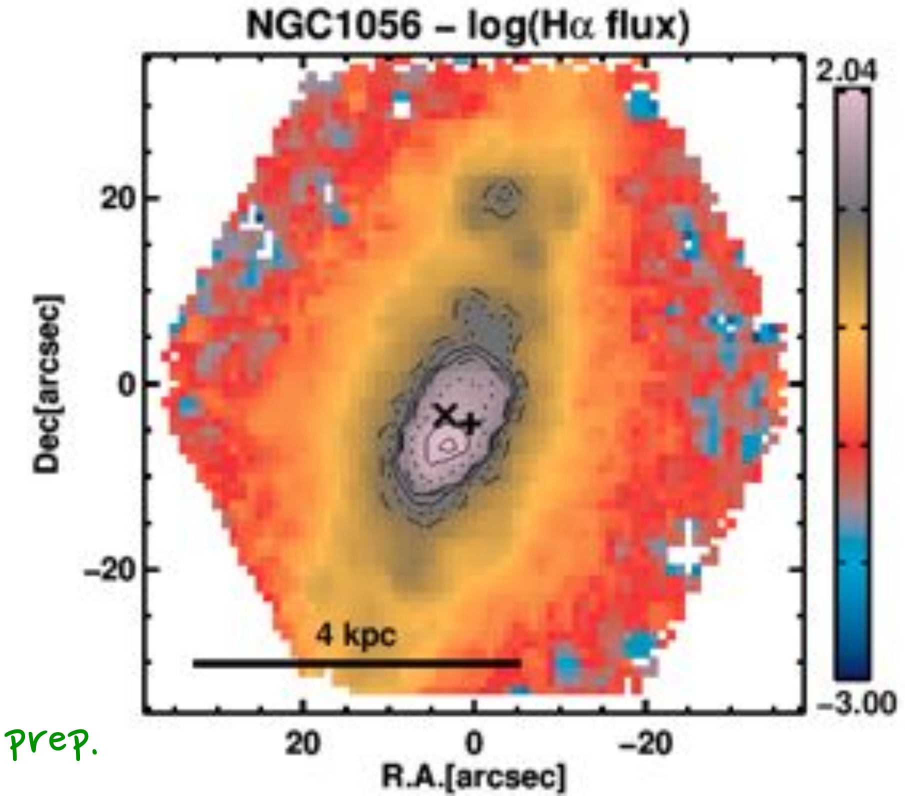
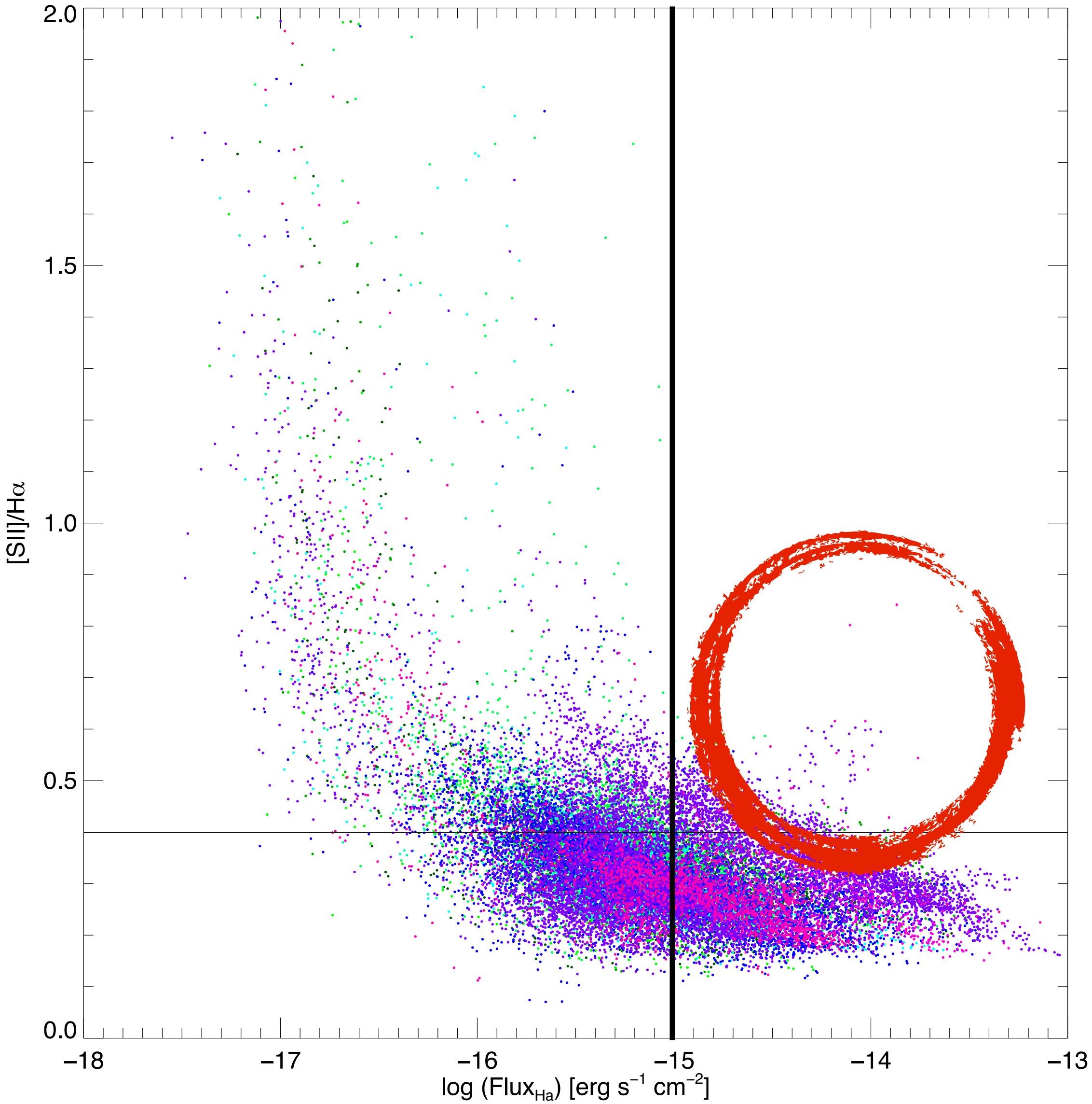


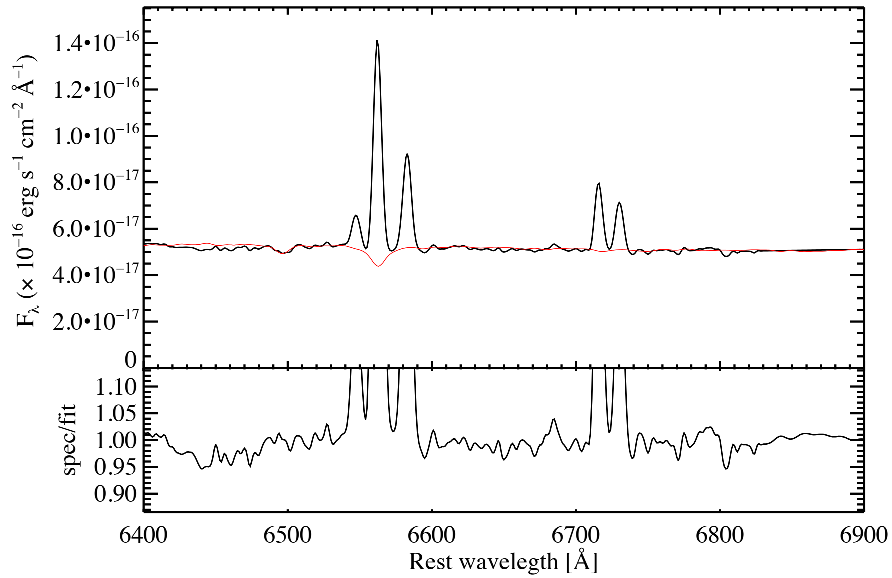


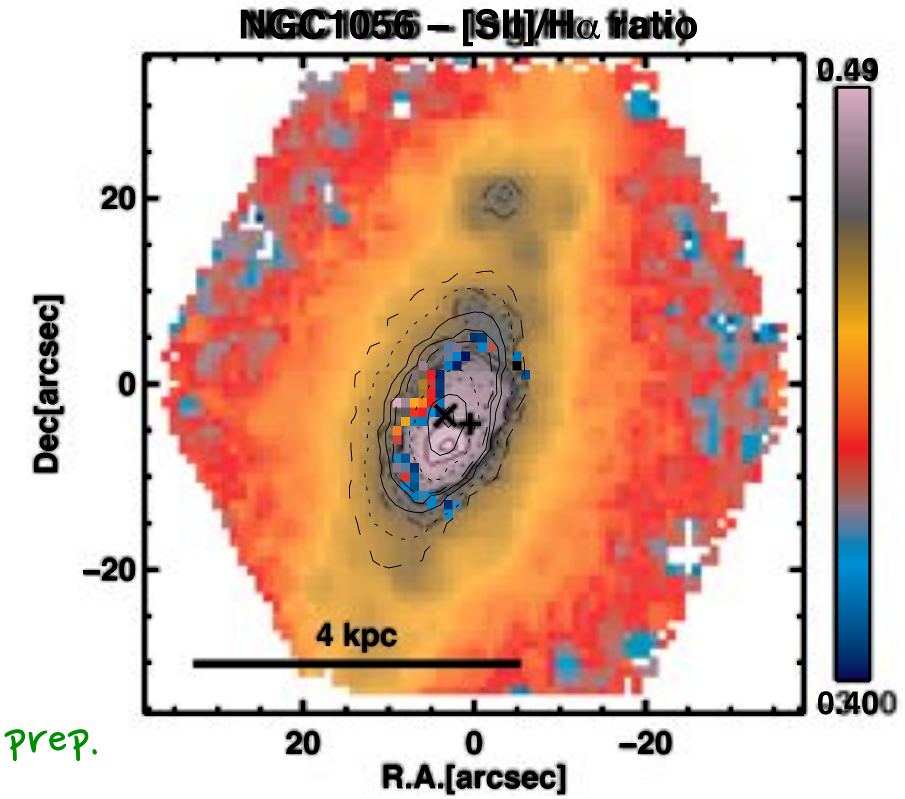


Galbany+ in prep.

SN remnants in CALIFA







Galbany+ in prep.

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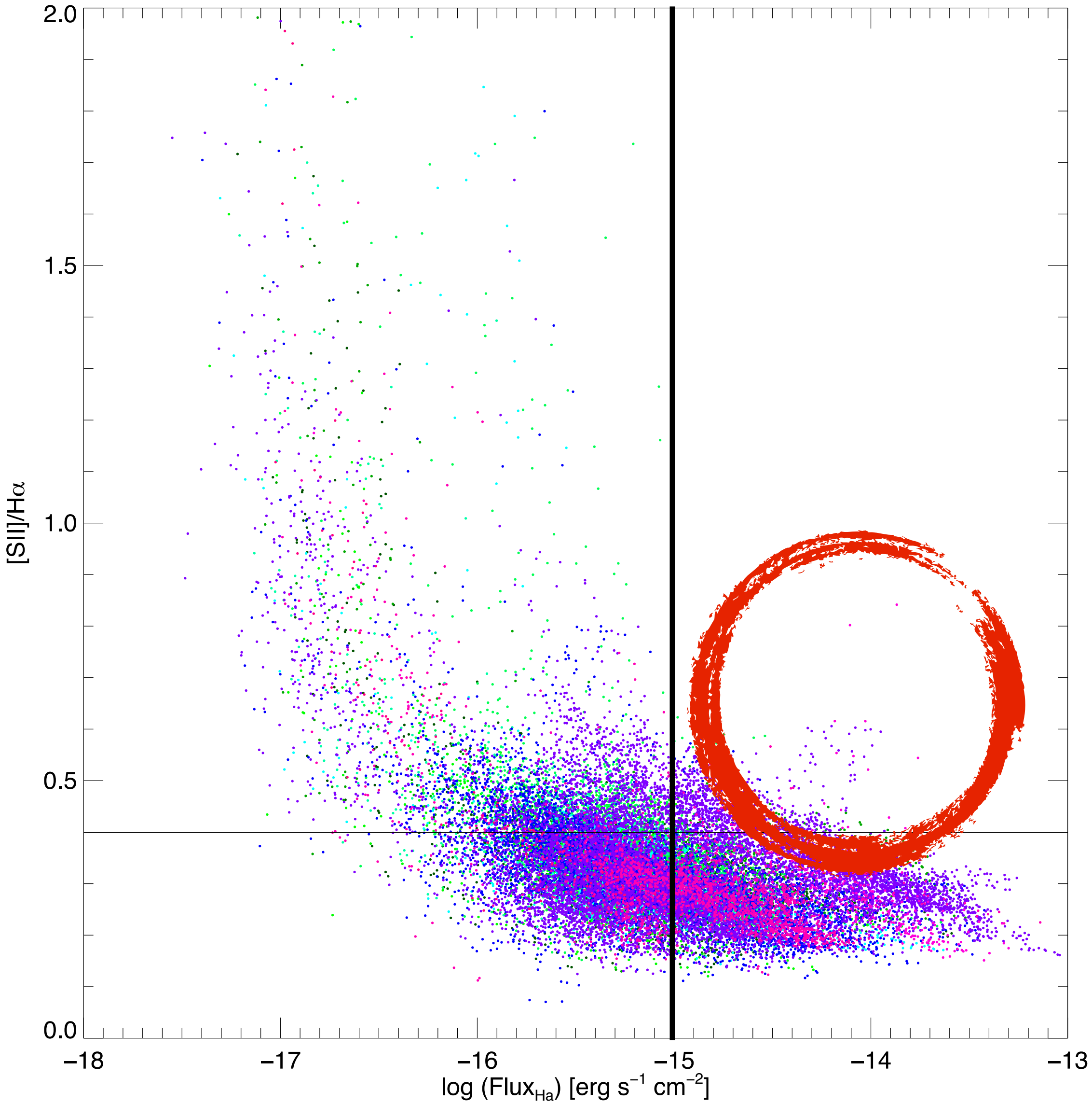
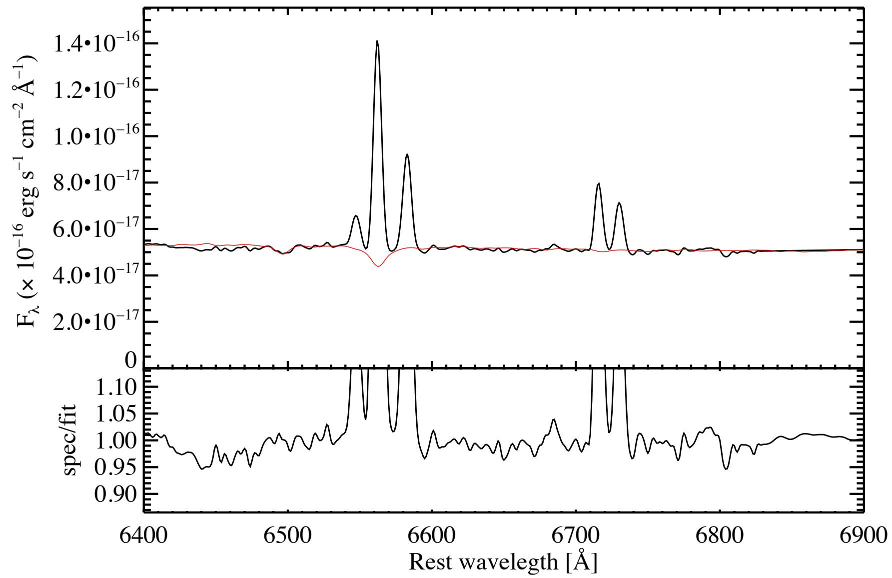
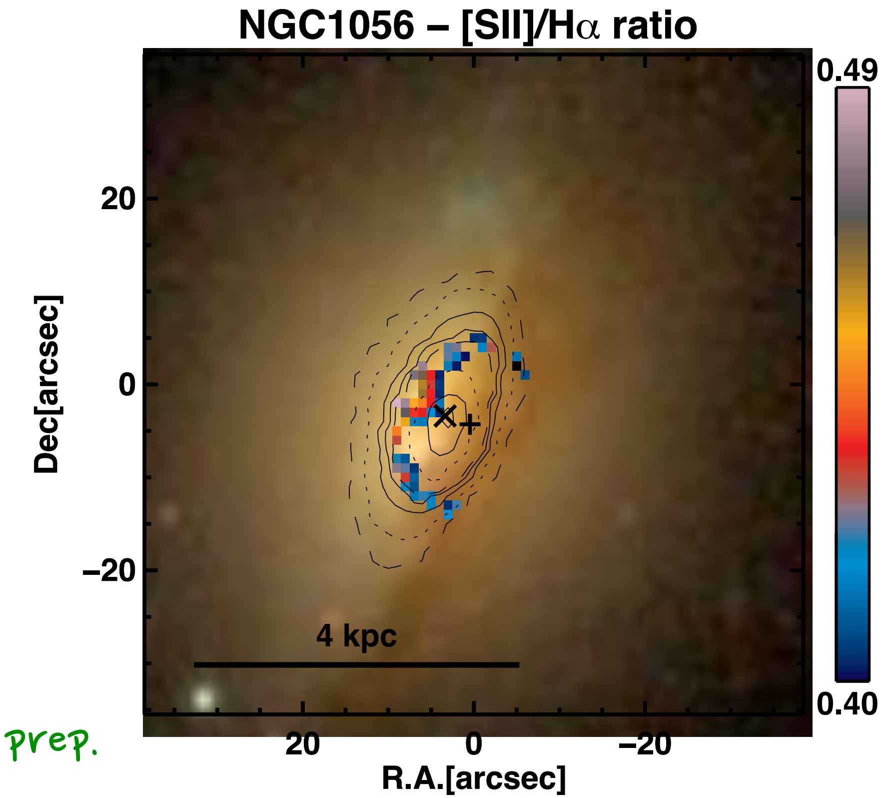


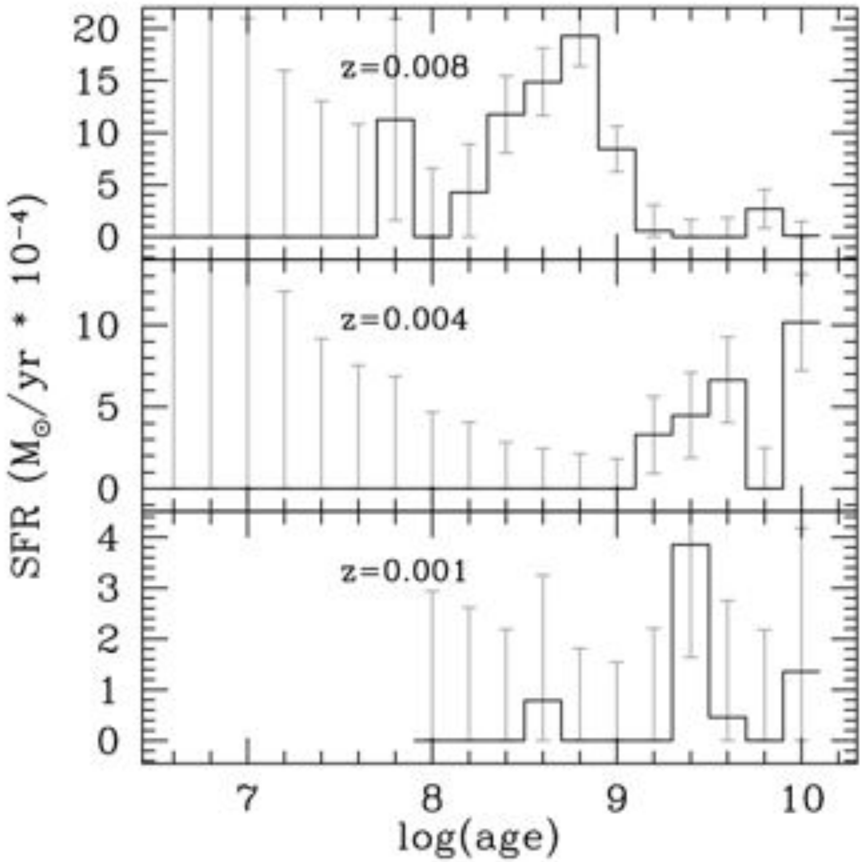




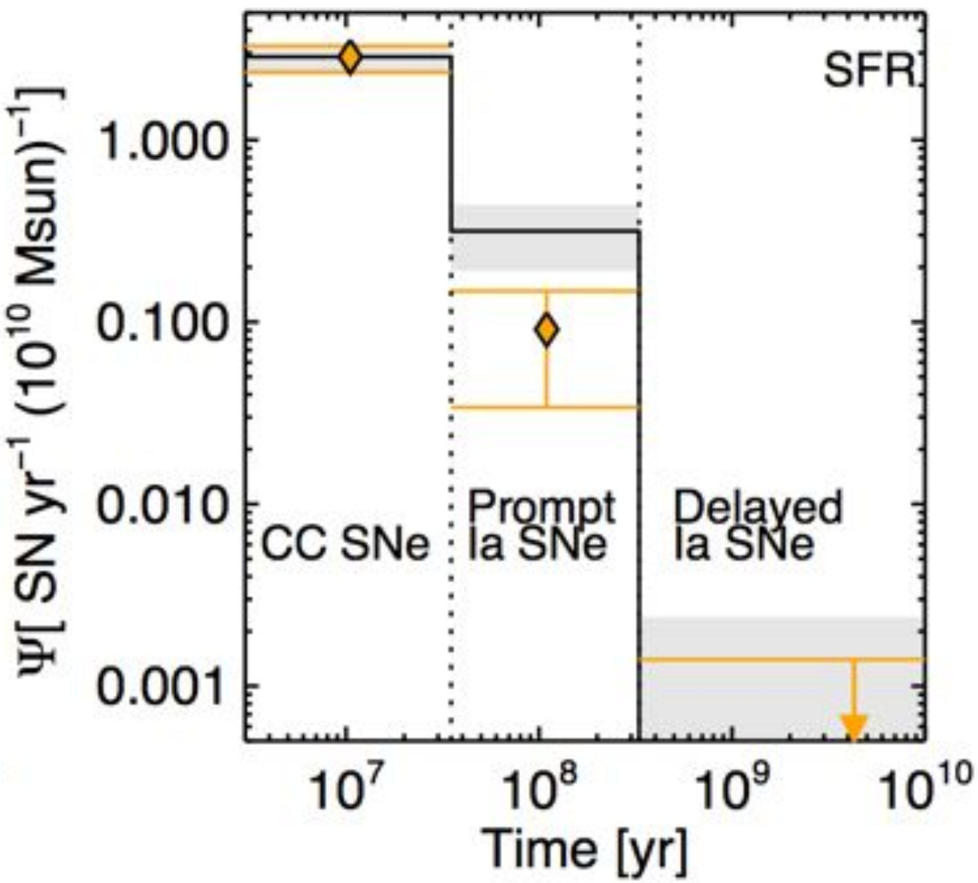
Galbany+ in prep.

SN delay time distribution (DTD) from SFH

col.: C. Badenes, U. Pittsburgh



Maoz+10



Recover the DTD from the SFH of SN locations

$$r_i \approx \sum_{j=1}^{K} m_{ij} \Psi_j$$

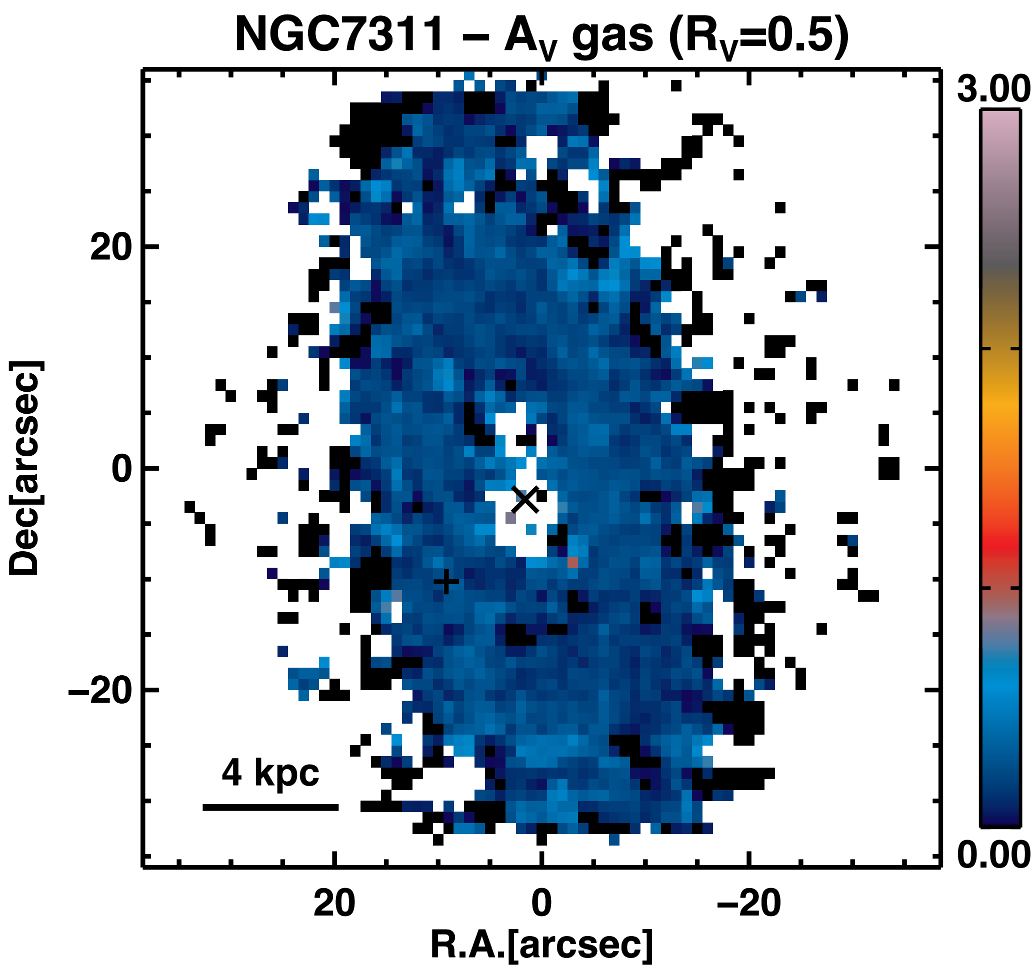
where m_{ij} is the SFH at each pixel (i) and age bin (j)
and Ψ_j is the mean DTD over the jth bin

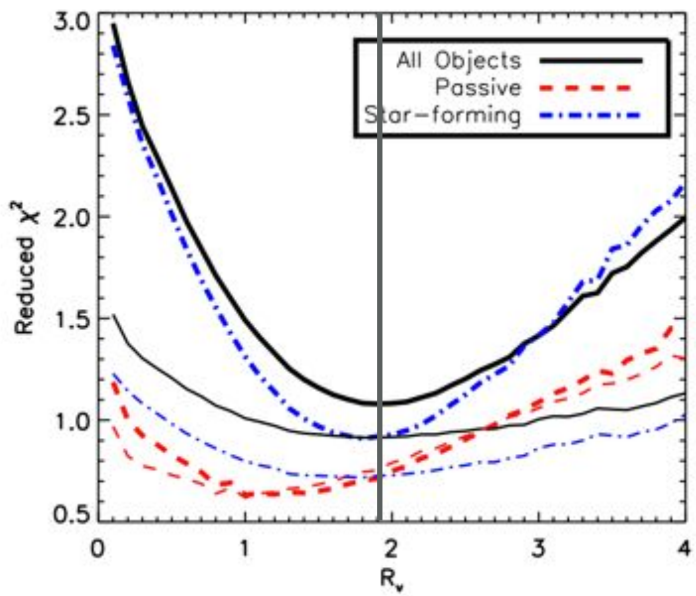
Galbany+ in prep.

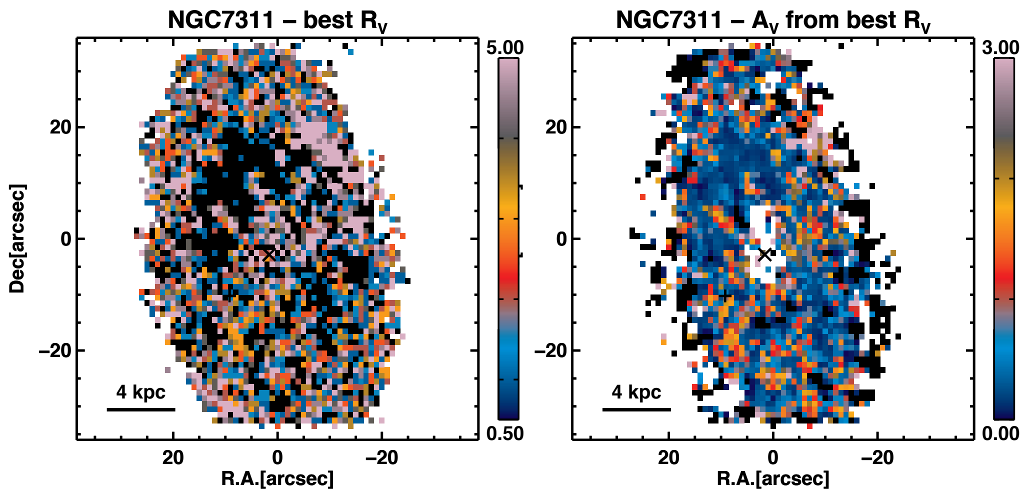
Extinction and reddening law: variable Rv

col.: S. Gonzalez-Gaitan, U. Chile

lower Rv values would explain high reddening due to CSM interaction







Gonzalez-Gaitan+ in prep.

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col.: S. Gonzalez-Gaitan, U. Chile

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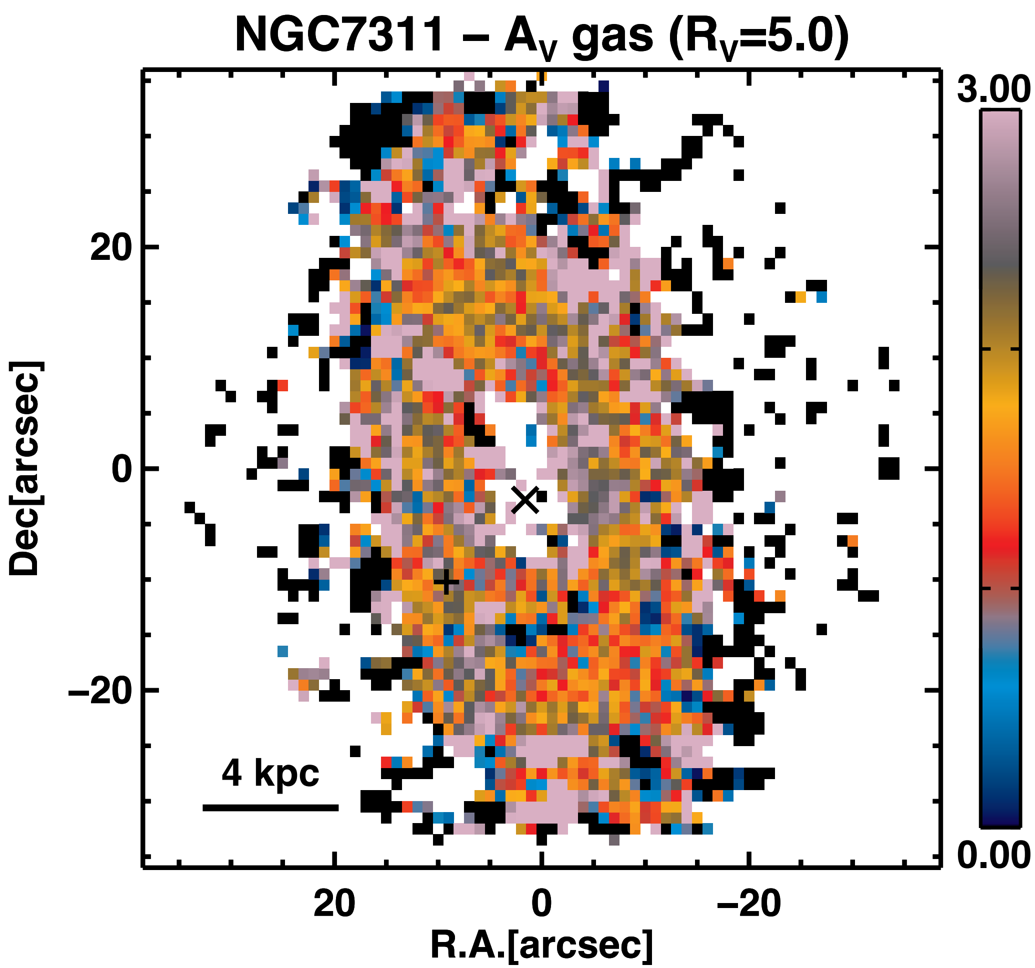
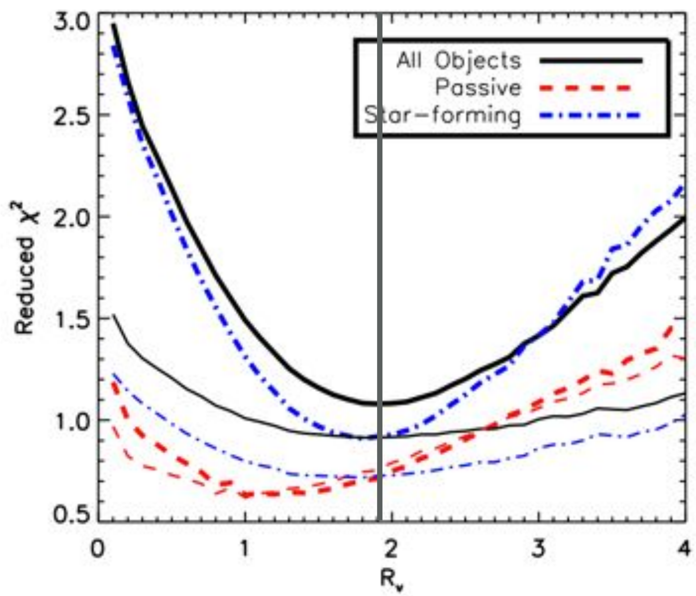
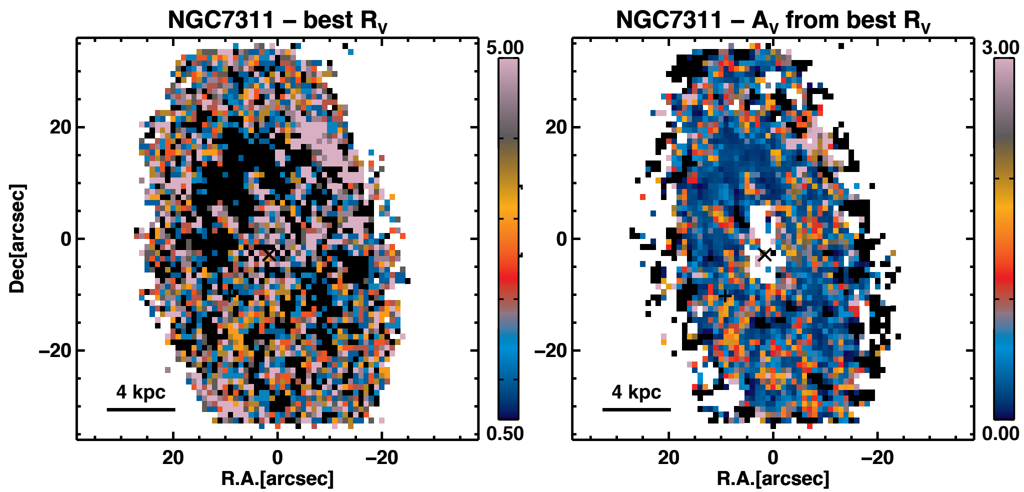


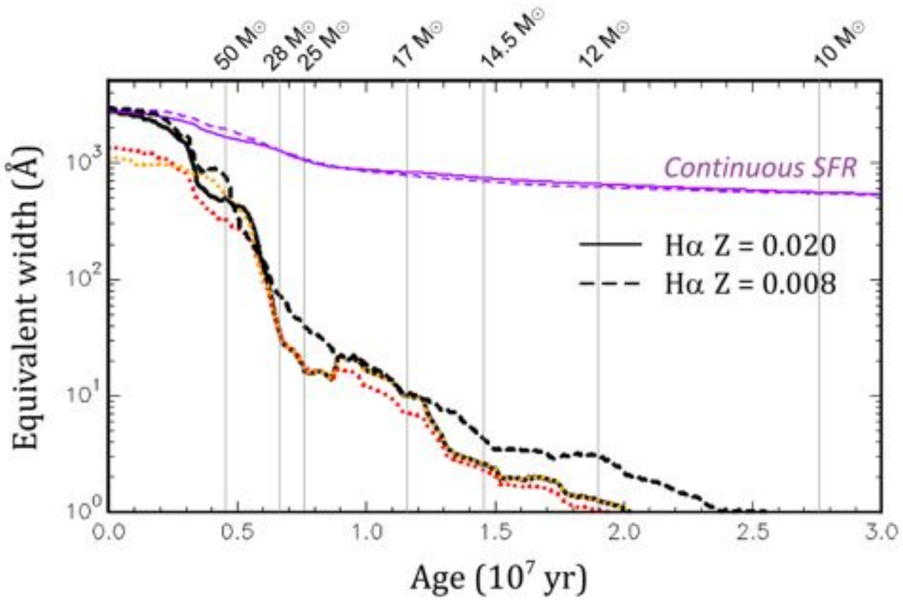




Gonzalez-Gaitant in prep.

SN parent cluster

col.: H. Kuncarayakti, U. Chile



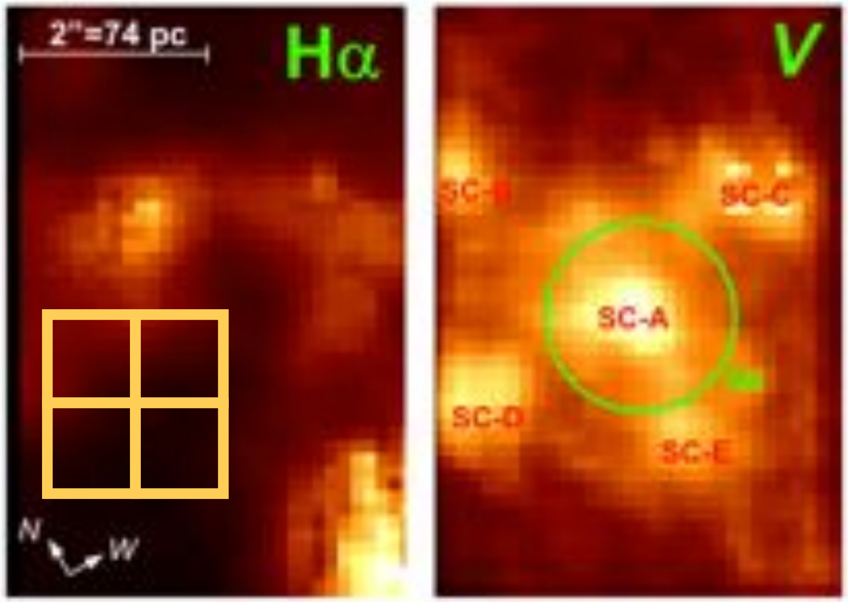
SINFONI

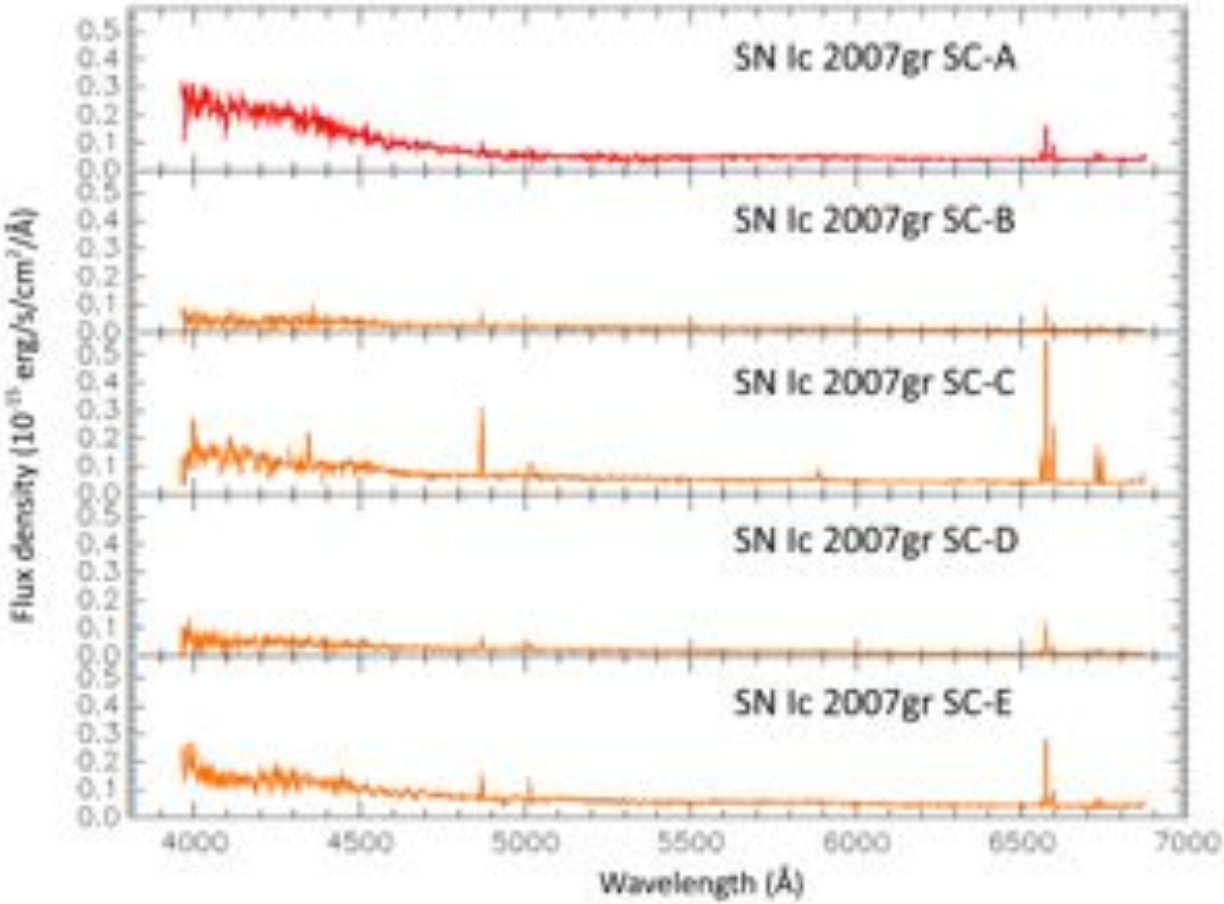
IMACS

SNIFS

GMOS

...





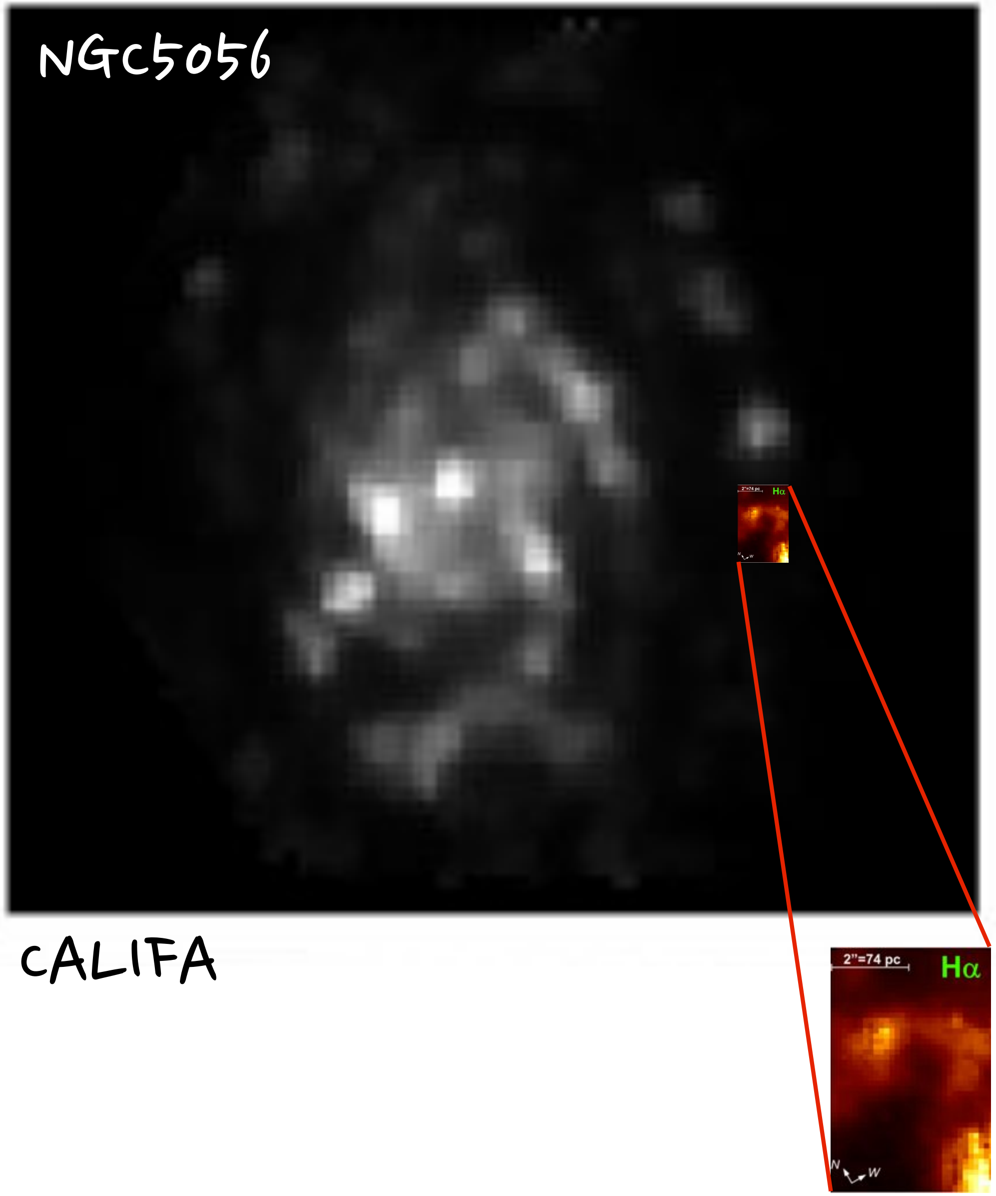
Kuncarayakti+ 2013ab, in prep.

MUSE Science verification

60.A-9329: SN environments (PI:Galbany)

col.: H. Kuncarayakti, U. Chile & J. P. Anderson. ESO

~1 arcmin ~1 arcmin



CALIFA

GMOS

MUSE Science verification

60.A-9329: SN environments (PI:Galbany)

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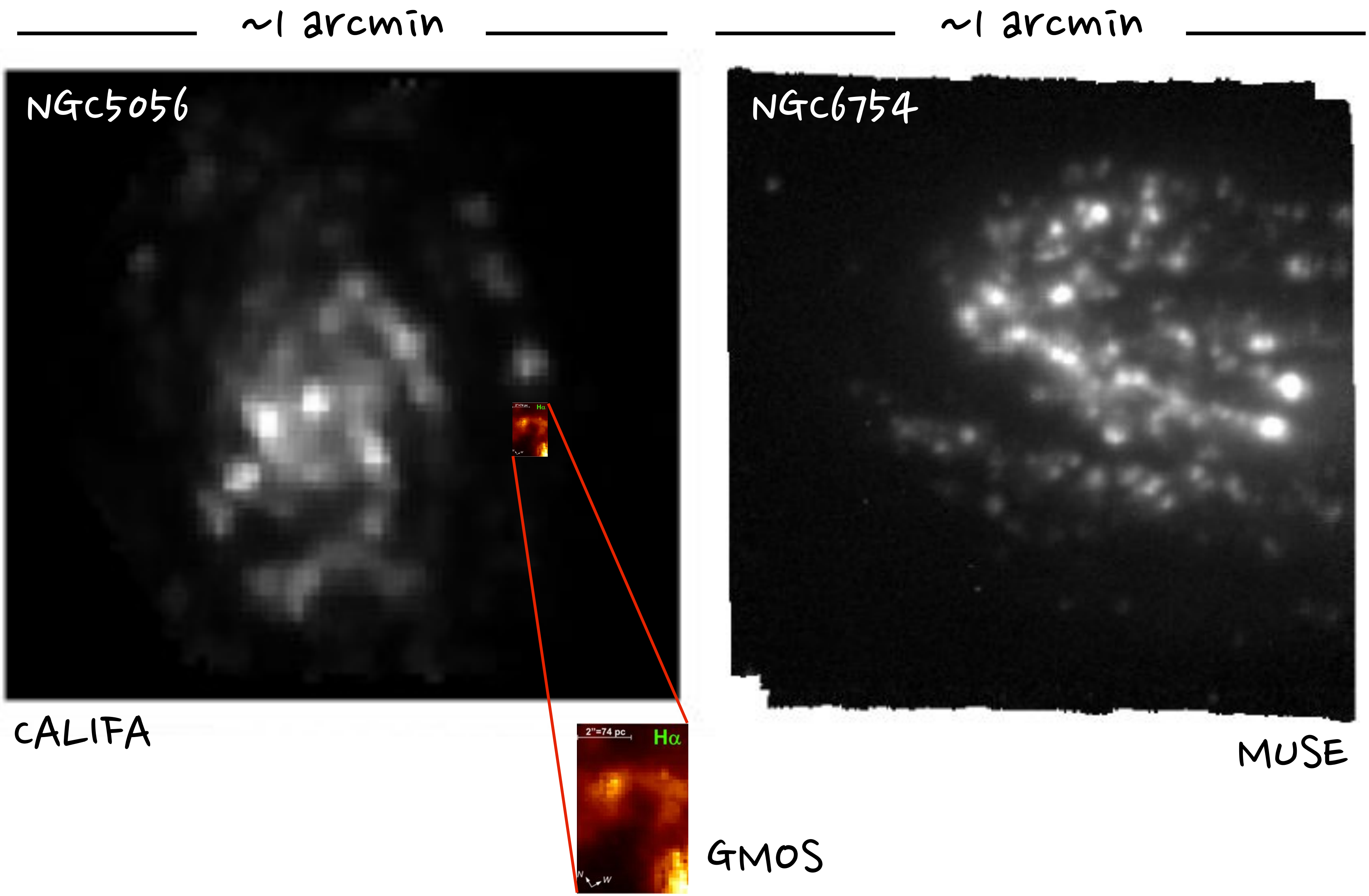

summary and conclusions

- IFS is a powerful technique at low redshift (AND CONFUSING SOMETIMES!!)
- differences found in galactocentric distances. This can be understood as differences in the progenitor metallicity, in sequence from type Ibc/IIb, type II, and type Ia SNe.
- differences found in association to star-forming regions. This can be understood as differences in the progenitor mass and age, in the same SN type sequence.
- no differences found in type Ibc/IIb and type II SNe environmental metallicities, giving support to the progenitor mass and age to determine the SN type. SNe Ia occur systematically in metal-richer environments.
- differences between local and integrated values can be understood as uncertainties on the estimations of these parameters at high redshift. Although not so important for SNe Ia.
- more SN-IFU projects on-going (SNR, DTD, Rv, SNIa LC-host, AGN, Z-rings…)
- other IFU instruments with different FoV and resolution can be more appropriate for your study!

Thanks, and be prepared for the tutorial!

(H6.1 Tuesday 15:30)

constel•lacions - L'estel matinal, Joan Miró, 1940